RE-ORDER NO. 65-852

Report No. TE-18-66

FINAL DESIGN DOCUMENTATION

FOR

SIX-CONVERTER THERMIONIC GENERATOR DESIGN

Contract No. 951230

October 1965

by

P. J. Brosens

Prepared For

Jet Propulsion Laboratory
Pasadena, California

Approved by: George N. Hatsopoulos
G. N. Hatsopoulos,
President

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

Thermo Electron Engineering Corporation, 85 First Avenue, Waltham, Massachusetts 02154

NOTICE

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SUMMARY

This Design Documentation constitutes the final report of work done by Thermo Electron Engineering Corporation on the Design of a Six-Converter Thermionic Generator for the Jet Propulsion Laboratory under Contract No. 951230. The Documentation includes the design analysis for the generator, and all drawings required for the fabrication of a generator prototype which includes an electron bombardment unit for electrical heating. In addition, suggested materials suppliers, treatment of parts, assembly flow charts, and assembly instructions are given.

NOMENCLATURE

Ai	Absorptivity of cavity surface i
B	Effective emissivity of shielded surface
Cij	Conduction heat transfer coefficient between elements i and j, watts/^{o}K
D_m	Mirror diameter, in.
D	Cavity aperture diameter, in.
e	Cylinder height of converter heat loss area, cm.
Ei	Emissivity of cavity surface i
f	Focal length, in.
Fi	Fraction of solar input striking surface i
Fij	View factor from surface i to surface j
H	Distance from bottom of cavity to pseudo flux source, cm.
Hi	Total thermal flux input arriving at surface i
ℓ	Longitudinal thermal expansion, mils
Pi	Radiative power of black body at temperature Ti, watts/sq. cm.
Pii	Thermal flux radiated directly by all cavity surfaces to surface i, watts
Qi	Net heat input to surface i, watts
QC	Net heat received by emitter piece of each converter, watts
r	Radial thermal expansion, mils
Ri	Radial dimension of cavity surface element i, cm.
Si	Surface area of cavity element i, sq. cm.
t	Thickness of support sleeve, rear cavity piece and thickness of electron bombardment unit support element, mils
Ti	Temperature of surface i, ^{o}K
Vi	Total solar flux arriving at surface i, watts

W_i	Input solar flux striking surface i, watts
W	Total solar flux entering generator cavity, watts
Y	Intermediate function for the calculation of view factors
Z_i	Cavity dimension of element i, cm
ϵ	Change in critical clearance, mils
θ_i	View angle from pseudo flux source to element i, degrees
ψ_i	Solid view angle to element i, steradians

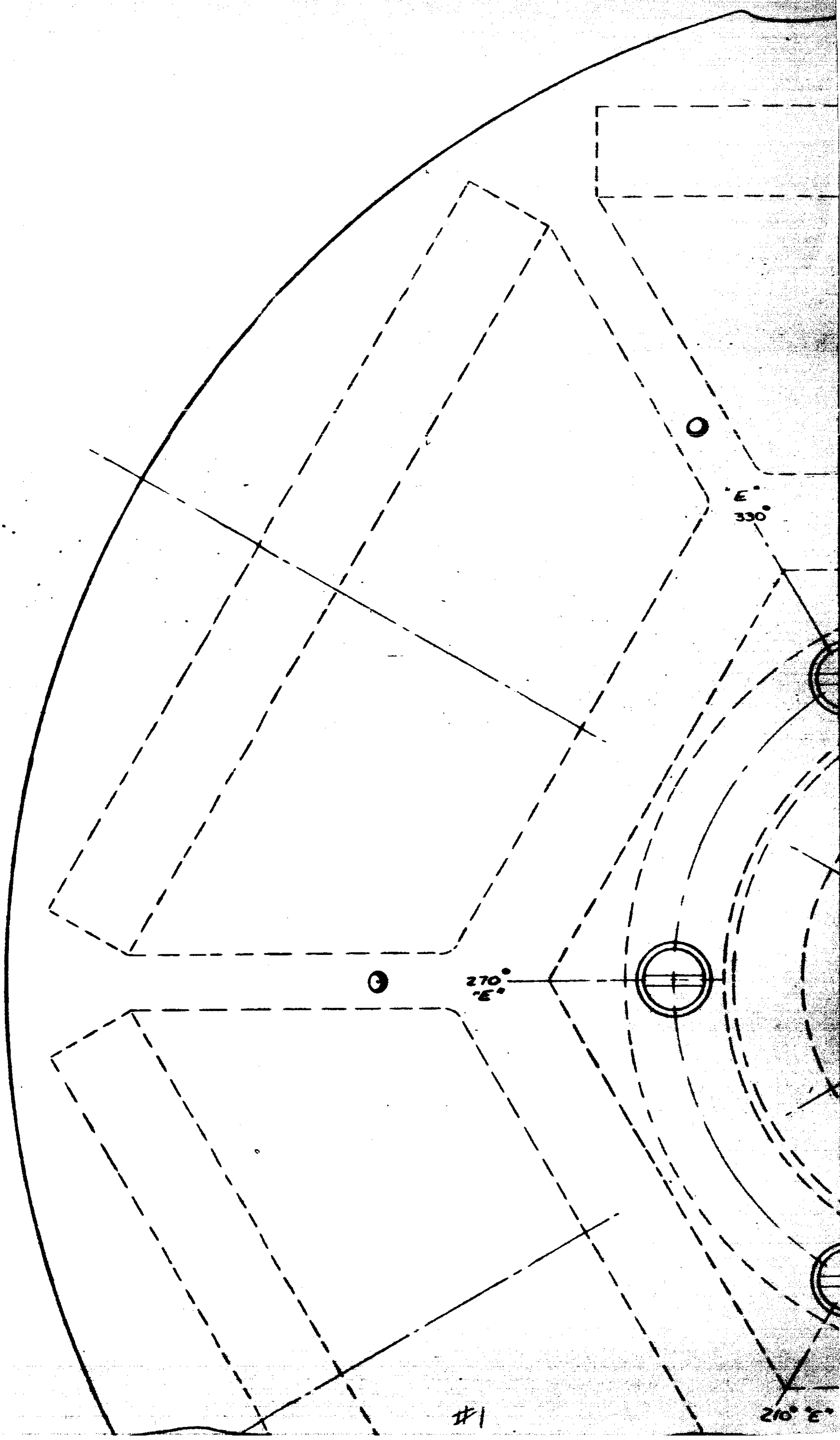
1.1 Preliminary Design of 6-Converter Generator

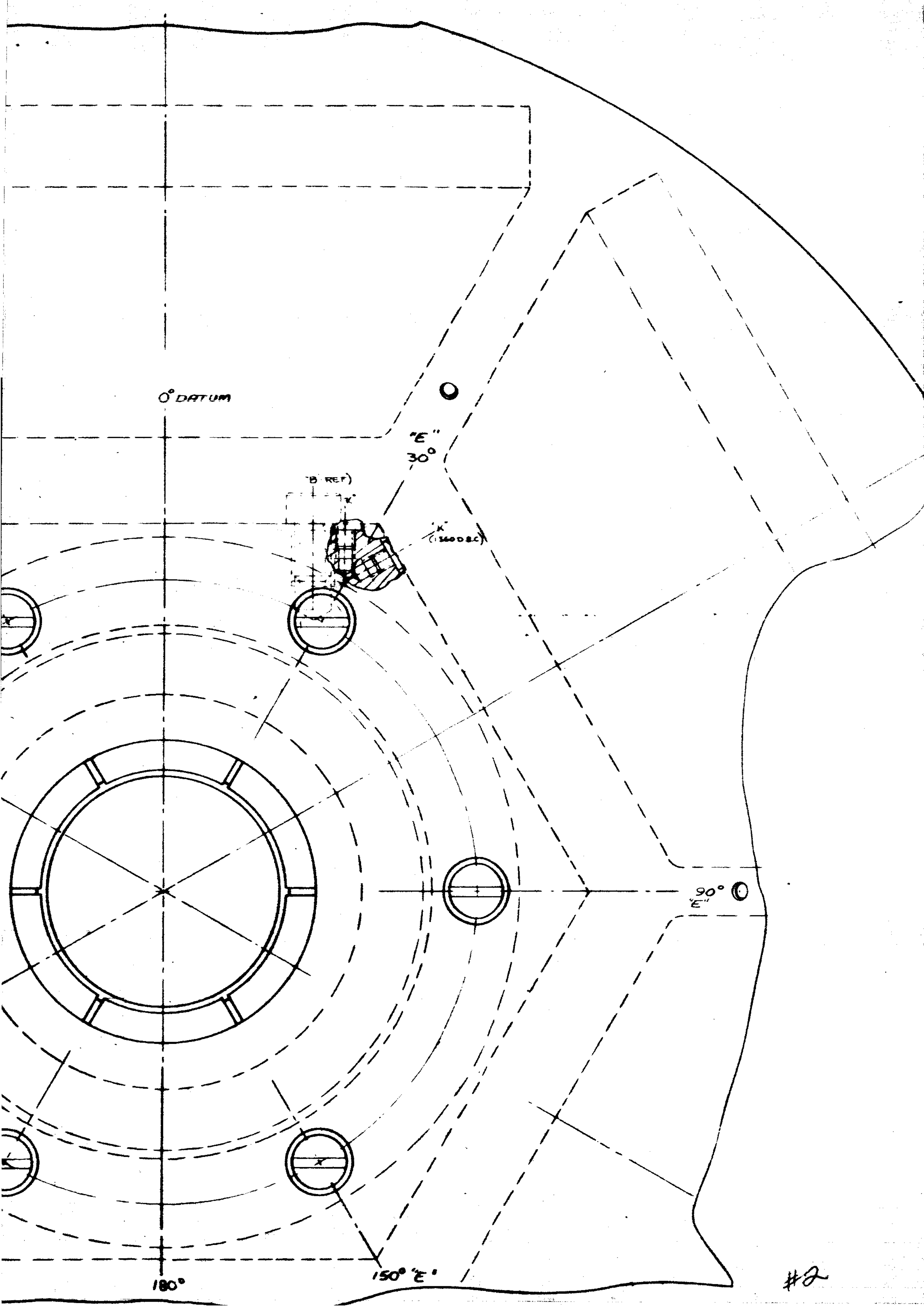
The preliminary layout of the 6-converter generator as submitted to JPL is shown on Figures 1, 2 and 3, TEE Dwg. 550-1000, Sheets 1, 2 and 3. These show correspondingly the geometry of the generator, the shoe-piece modifications required to the Series VIII converter, and the required support structure for mounting the generator in the JPL vacuum chamber.

The geometry of the generator selected attempts meeting specified design conditions:

1. All converters must have identical view angles to the heat source to insure uniform heating.
2. All converters must remain compatible for use in Generator JG-3, developed under JPL Contract 950671.
3. The generator must be compatible with a concentrator having a rim angle of 55 degrees.
4. Radiation shield shapes must be such as not to distort as a result of time at temperature or thermal cycling.
5. The generator must be capable of handling its heat transfer in a completely autonomous manner.

To meet the first condition, it is evident that in order for the 6 converters to have an identical view angle of the heat source, their principal axis of symmetry must be symmetrically located on a conical surface. The apex angle of this cone defines the "angle of tilt" of the converters with respect to the optical axis of the generator. For an apex angle of 180°, the axes of symmetry of the converters lie like the radial spokes of a wheel. A preliminary design evaluation indicated that for any apex angle less than 180°, a mechanical interference between the radiators of the converters is produced, unless the converters are moved away from the optical axis. However, such modification of the converter


"E"
330°
270°
"E"
210° "E"
#1



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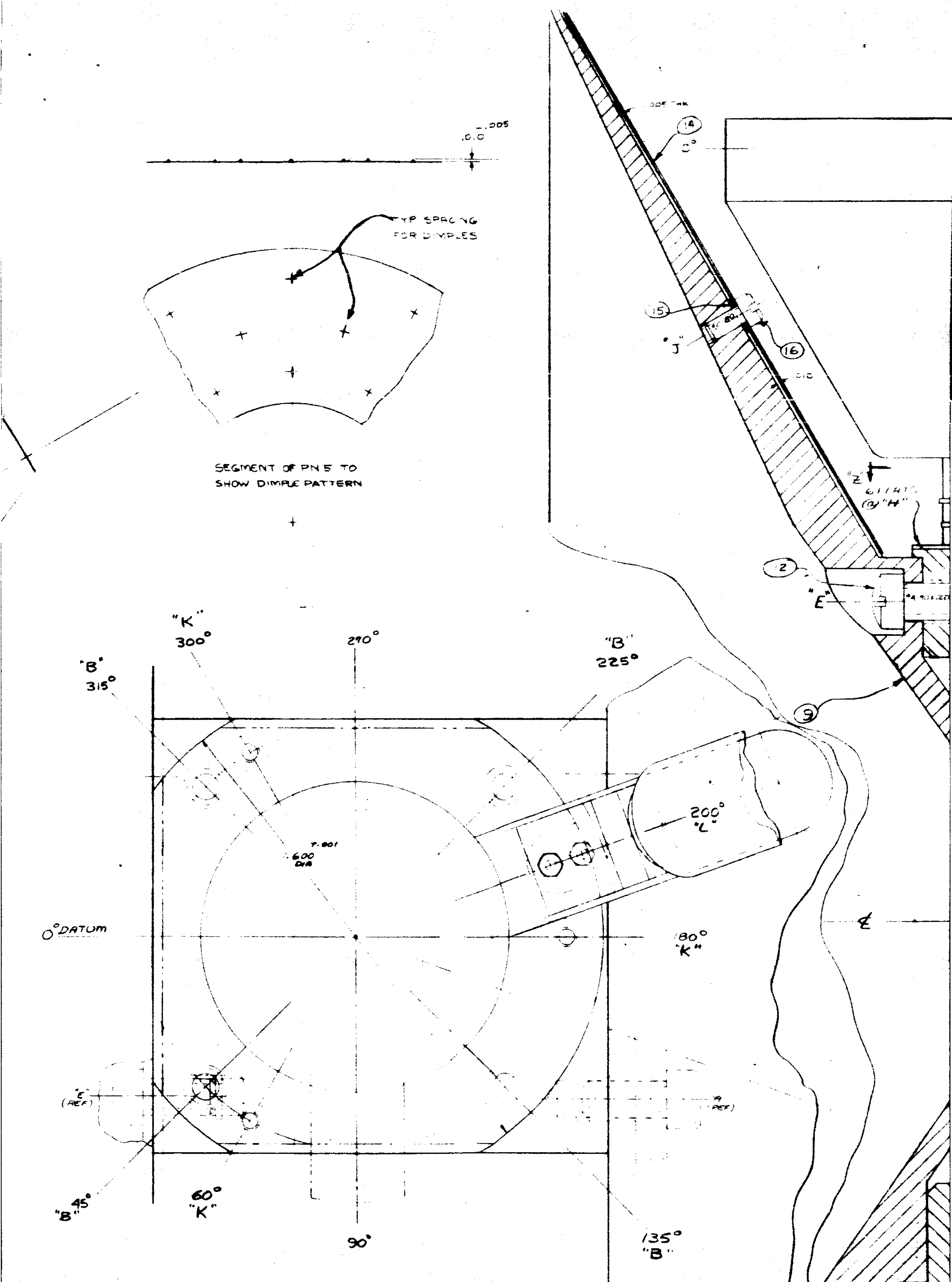
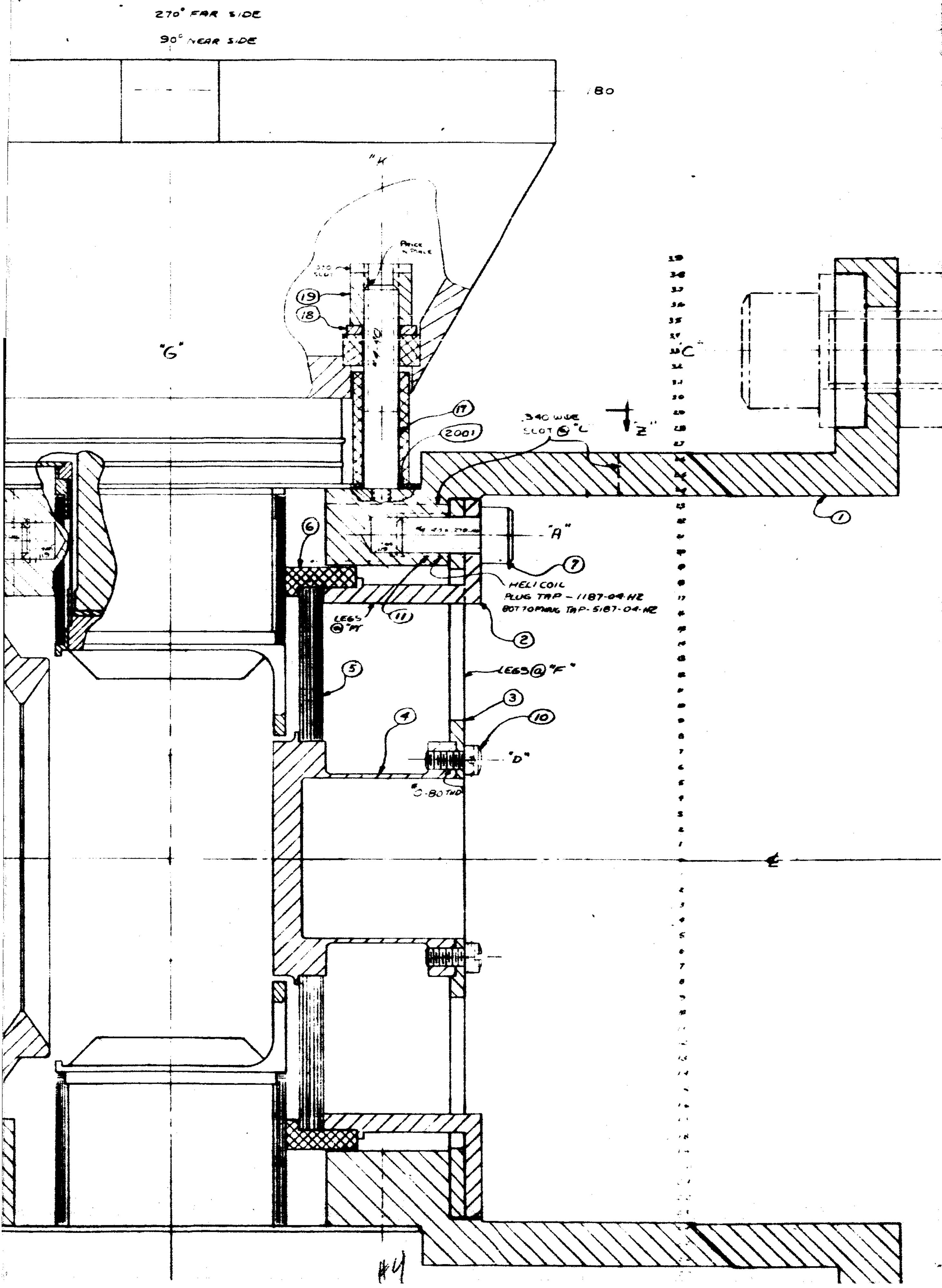


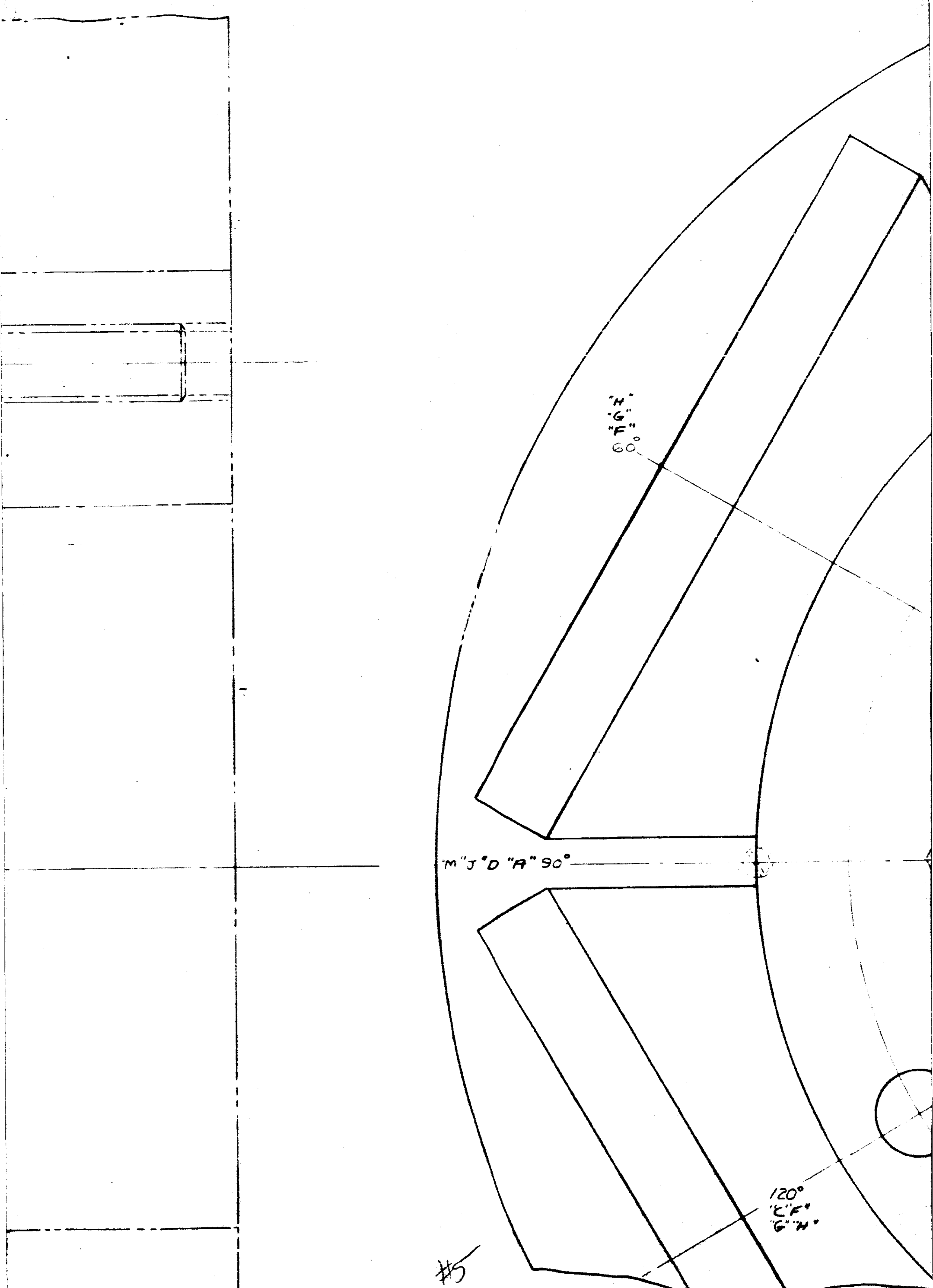
SEGMENT OF PN 5 TO SHOW DIMPLE PATTERN

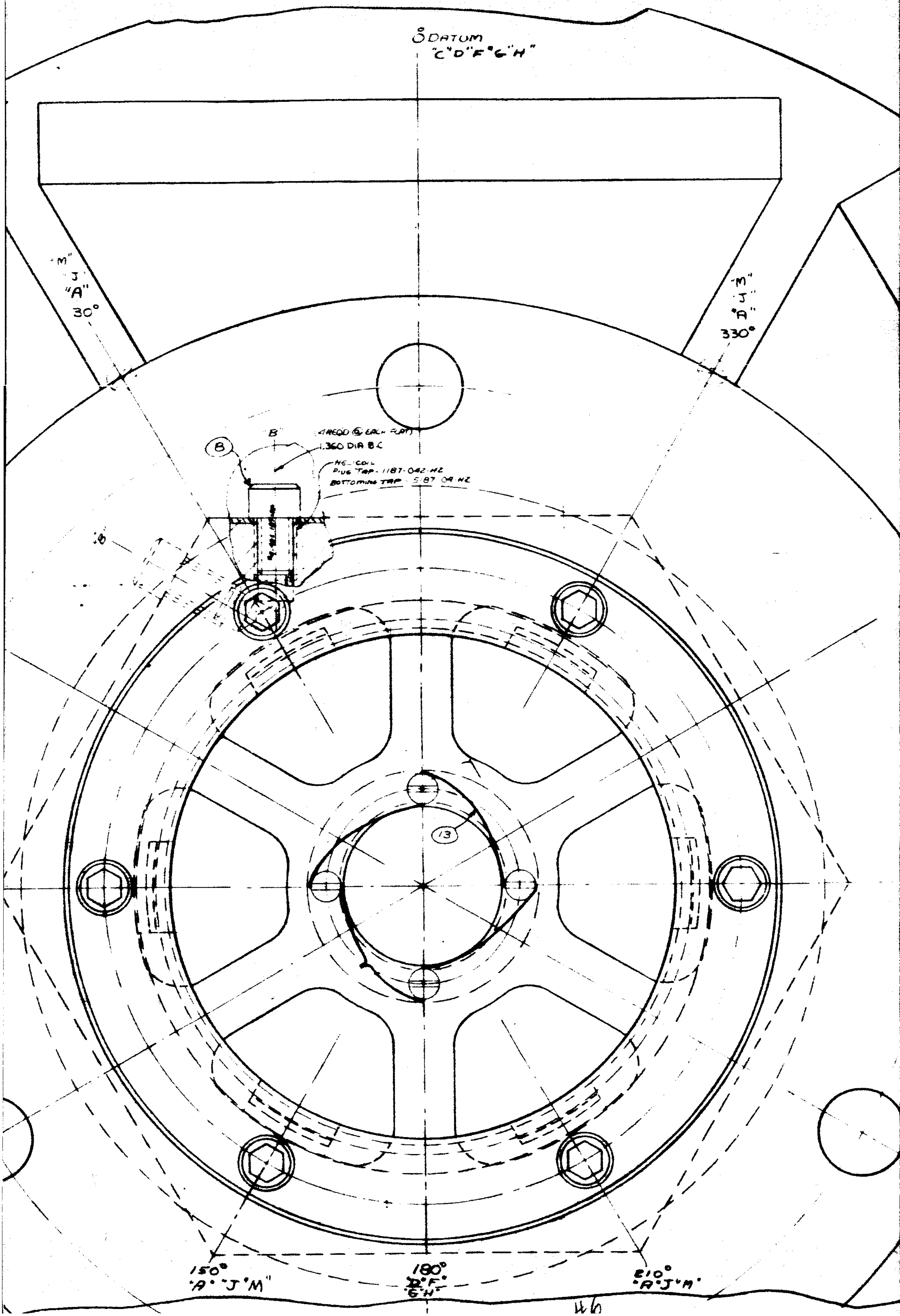
SECTION "Z-Z"

#3

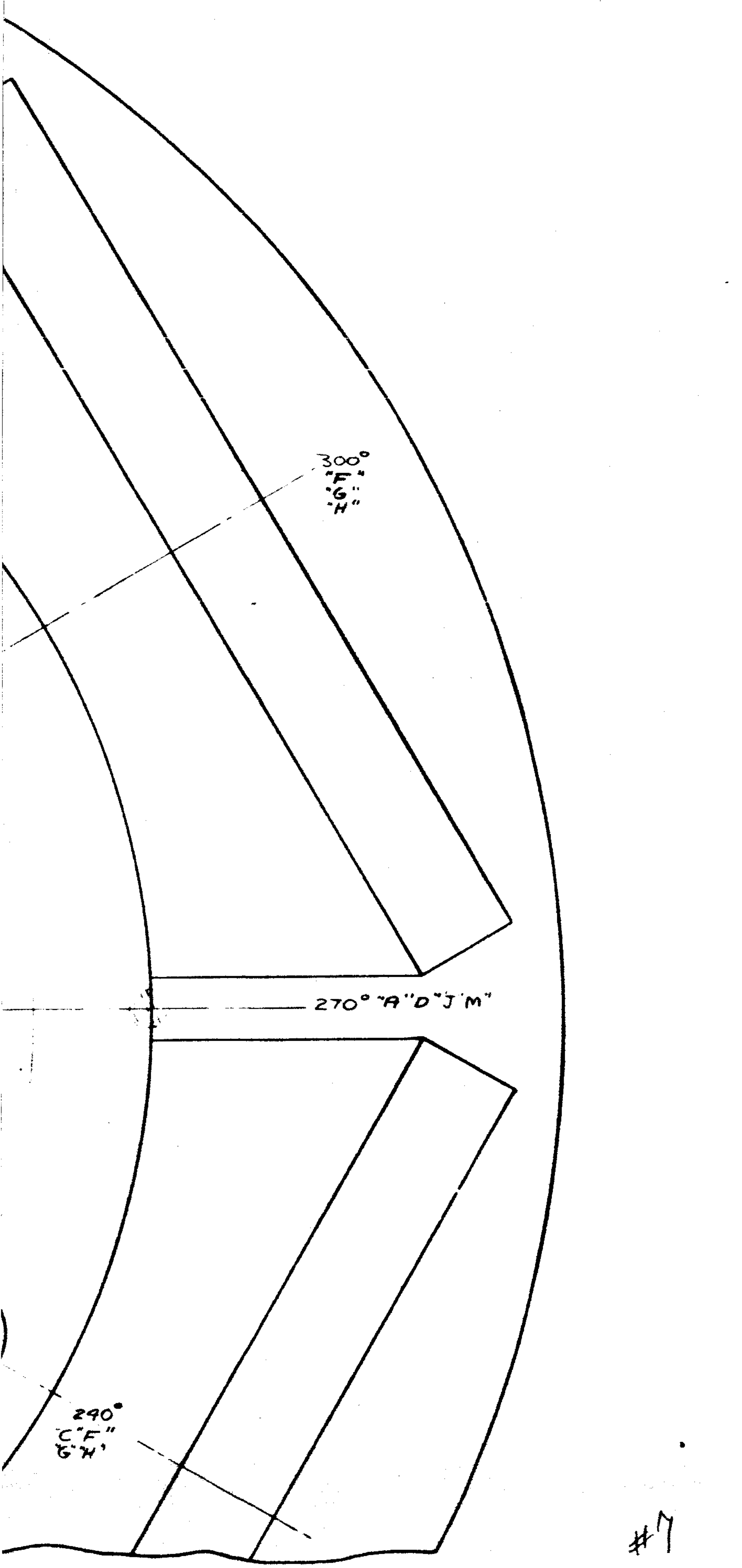


270° FAR SIDE
90° NEAR SIDE
.80
"K"
"G"
"C"
19
18
17
2001
.340 WIDE
SLOT @ "C"
"Z"
1
6
"A"
7
HELI COIL
PLUG TAP - 1187-04-HZ
BOTTOMING TAP-5187-04-HZ
11
2
5
LEGS @ "F"
3
10
4
"D"
0-80 THD
#4


"H"
"G"
"F"
60°
"M" "J" "D" "A" 90°
120°
"C" "F"
"G" "H"
#5



DATUM
"C" "D" "F" "G" "H"
"M"
"J"
"A"
30°
"M"
"J"
"A"
330°
B
B
(4 REQD @ EACH FLAT)
1.360 DIA B.C
HELI-COIL
PLUG TAP - 1187-042-HZ
BOTTOMING TAP - 5187-04-HZ
B
13
150°
"A" "J" "M"
180°
"D" "F"
"G" "H"
210°
"A" "J" "M"



#7

FIGURE 1

7 SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
6 UNK = UNKNOWN N.D = NO DRAWING, PROCURE FROM THIS L.D.
5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

	DATE	INIT	DATE	INIT.	DATE	INIT.	DATE	INIT.
DESIGN FINALIZED								

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	Y	Z									
1	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓																			
2																															
V																						✓									
II																															
⊥																															
⊙																															

#8

PART	SIZE	REQ	LOC	MAT'L	NOTES
BRAZES					
2001			18		.030 DIA WIRE
19			18	S.S	NUT
18			18	S S	WASHER
17			18	S.S	STUD
16			6	S.S	[illegible] X .125 [illegible]
15			6	Mo	WASHER
14			[illegible]	Mo	[illegible]
13			1	Mo	.020 [illegible]
12			6	Ta-W	#4-40 [illegible] LNG FHCS
11			36	[illegible]	#3585 [illegible] HELI COIL
10			4	Ta-W	#0-80 [illegible] .125 [illegible] (SP)
9			1	Mo	FRONT [illegible]
8			24	S S.	#4-40 X [illegible] LNG S.H.C.S
7			6	S S.	#4-40 X [illegible] LNG. S.H.C.S.
6			1	Al_2O_3	SHIELD INSULATOR
5			8	Mo	REAR SHIELD
4			1	Ta	[illegible] CAVITY PIECE
3			1	Nb	REAR CAVITY PIECE SUPPORT
2			1	Nb	REAR SHIELD HOLDER
1			1	MO	FRAME

PART	SIZE	REV	REQ	MAT'L	NOTES

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.000
FILLET RADIUS .010 MAXIMUM
THREADS. CLASS 2
DIA.CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

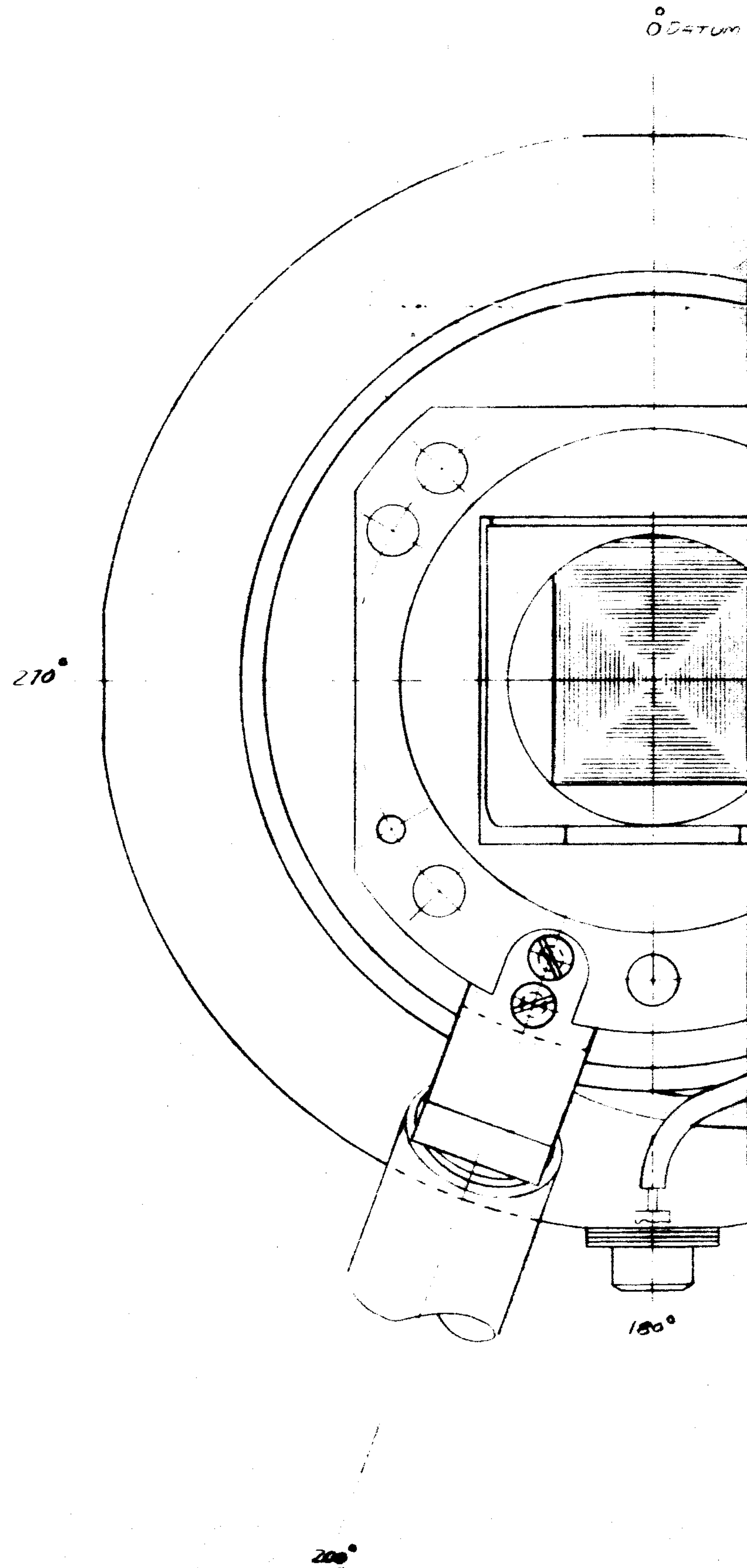
DRAWN	CHECKED	ENGINEER
P.F. M.V.	[illegible] 6-14-[illegible]	[illegible]

TITLE: 5 x CONVERTER GENERATOR

SCALE: 5 x 1	FINISH
NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
[illegible]	5F0-1000	1	

#9 ~~[illegible]~~ 2



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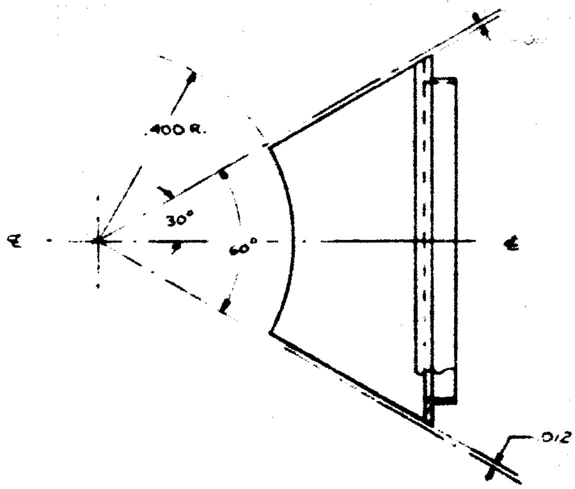
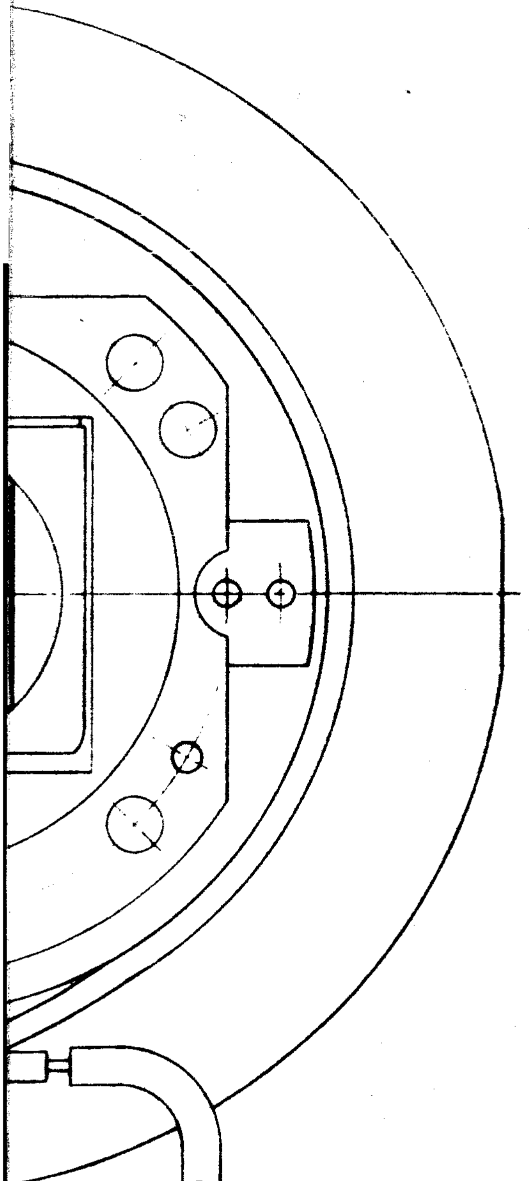
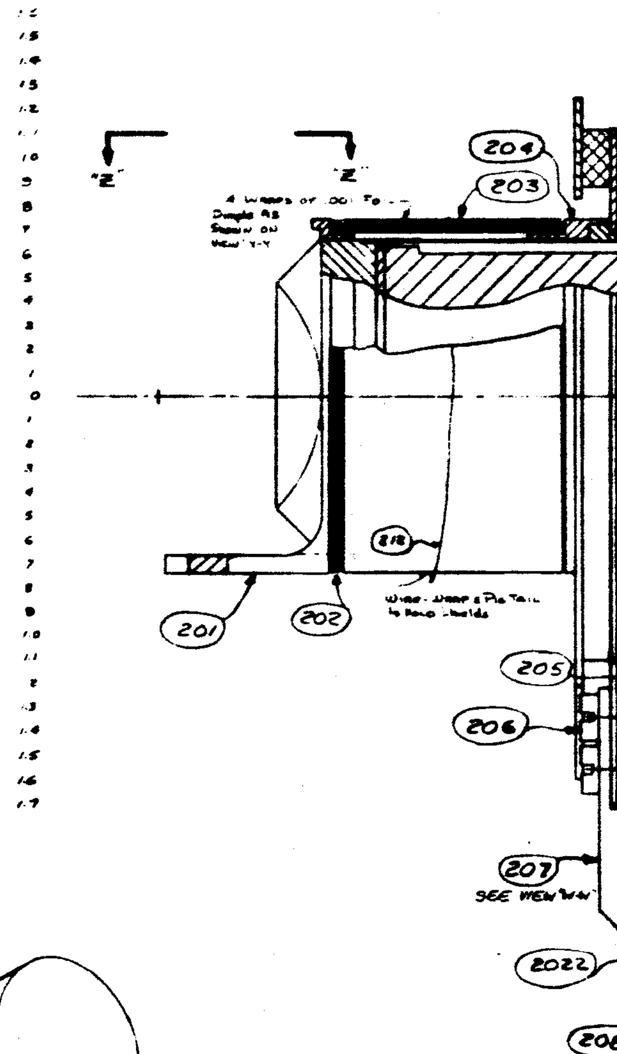
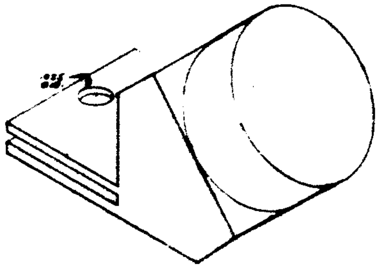


SECTION "Z-Z"
PN 201 SHOWN ONLY







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VIEW "W-W"

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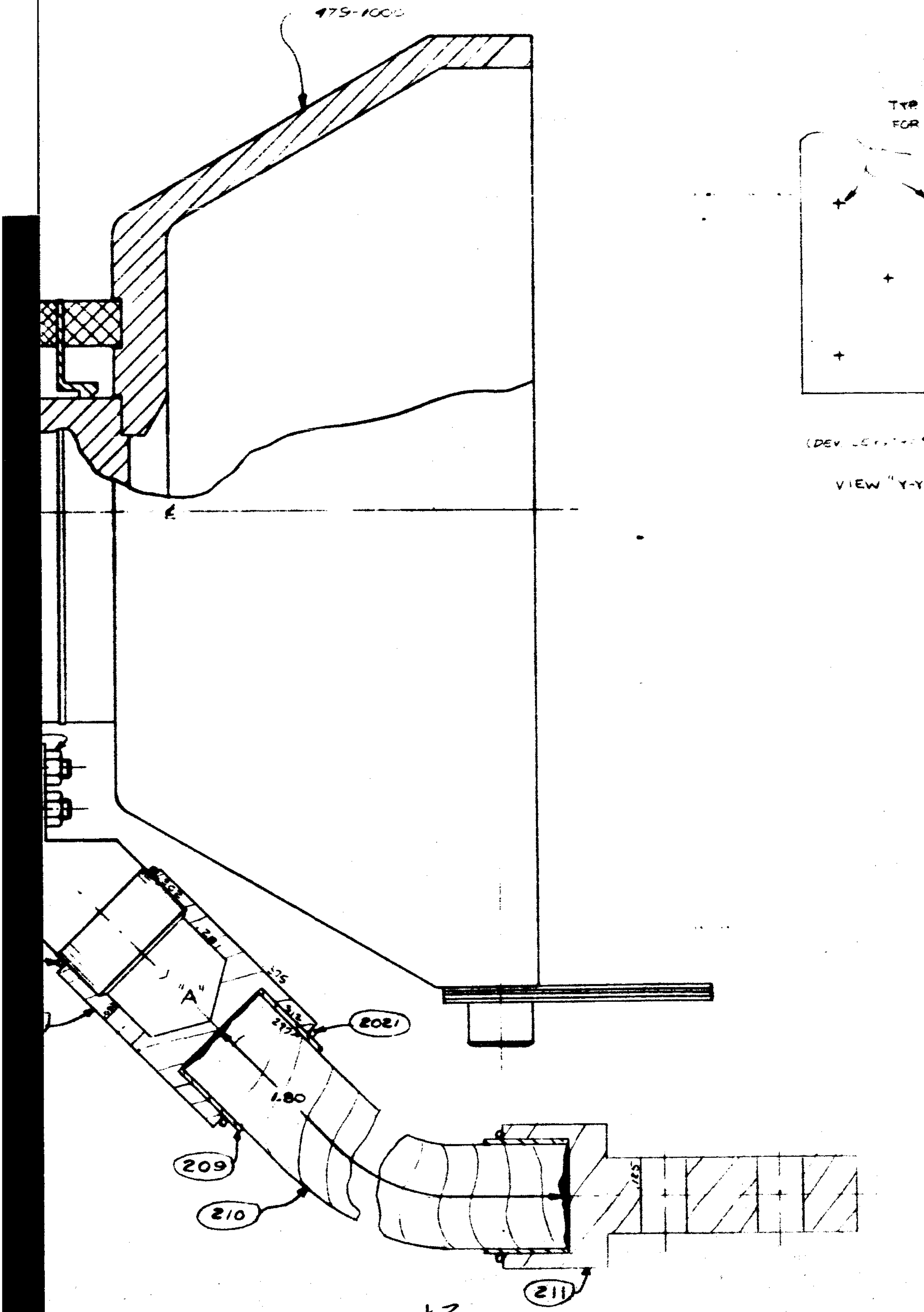

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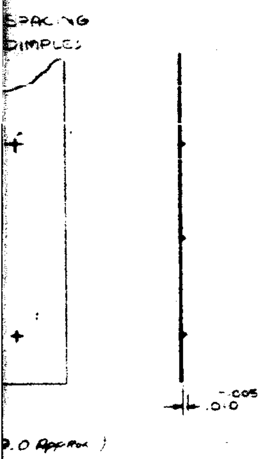


FIGURE 2

7	SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
6	UNK = UNKNOWN N D = NO DRAWING, PROCURE FROM THIS L.O.
5	DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4	ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3	MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2	SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1	NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

DESIGN FINALIZED	DATE	INIT	DATE	INIT	DATE	INIT	DATE	INIT

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	Y	Z
I																						
2																						
V																						
II																						
⊥																						
⊚																						

PART	SIZE	REV	REQ	MAT'L	NOTES
212			1	Mo	.003 WIRE
211			1	Cu	LEAD TERMINAL
210			1	Cu	LEAD
209			2	Ni	LEAD SLEEVE
208			1	Cu	LEAD ADAPTER
207			1	Nb	LEAD CLAMP
206	ND		2	S.S	[illegible]
205	ND		2	S.S	[illegible]
204			1	Ta	SHIELD SUPPORT
203			1	Ta	CONVERTER SHIELD (.001 THK)
202			5	Ta	SHOE PIECE SHIELD (.001 THK)
201			1	Ta	SHOE PIECE

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS .010 MAXIMUM
THREADS: CLASS 2
DIA CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ± 0° 9'
2.0-4.0 RAD ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 x 1 | FINISH:

NEXT ASSY | SIMILAR TO

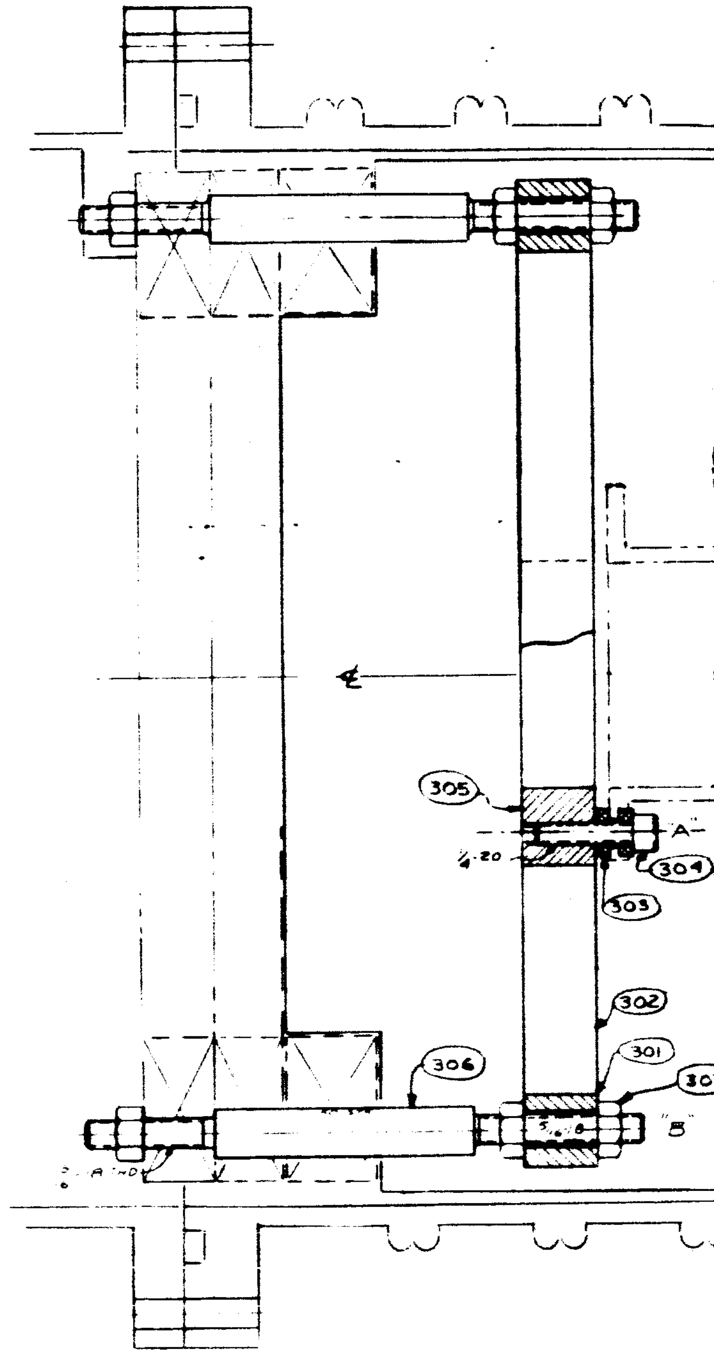
THERMO ELECTRON

DRAWN	CHECKED	ENGINEER
R.B. 6-17-69 M.N.	VP 6-17-69	[illegible]

TITLE: SIX CONVERTER GENERATOR (CONVERTER

SIZE	DRAWING NUMBER	SHEET	REV
	550-1000	2	

#4



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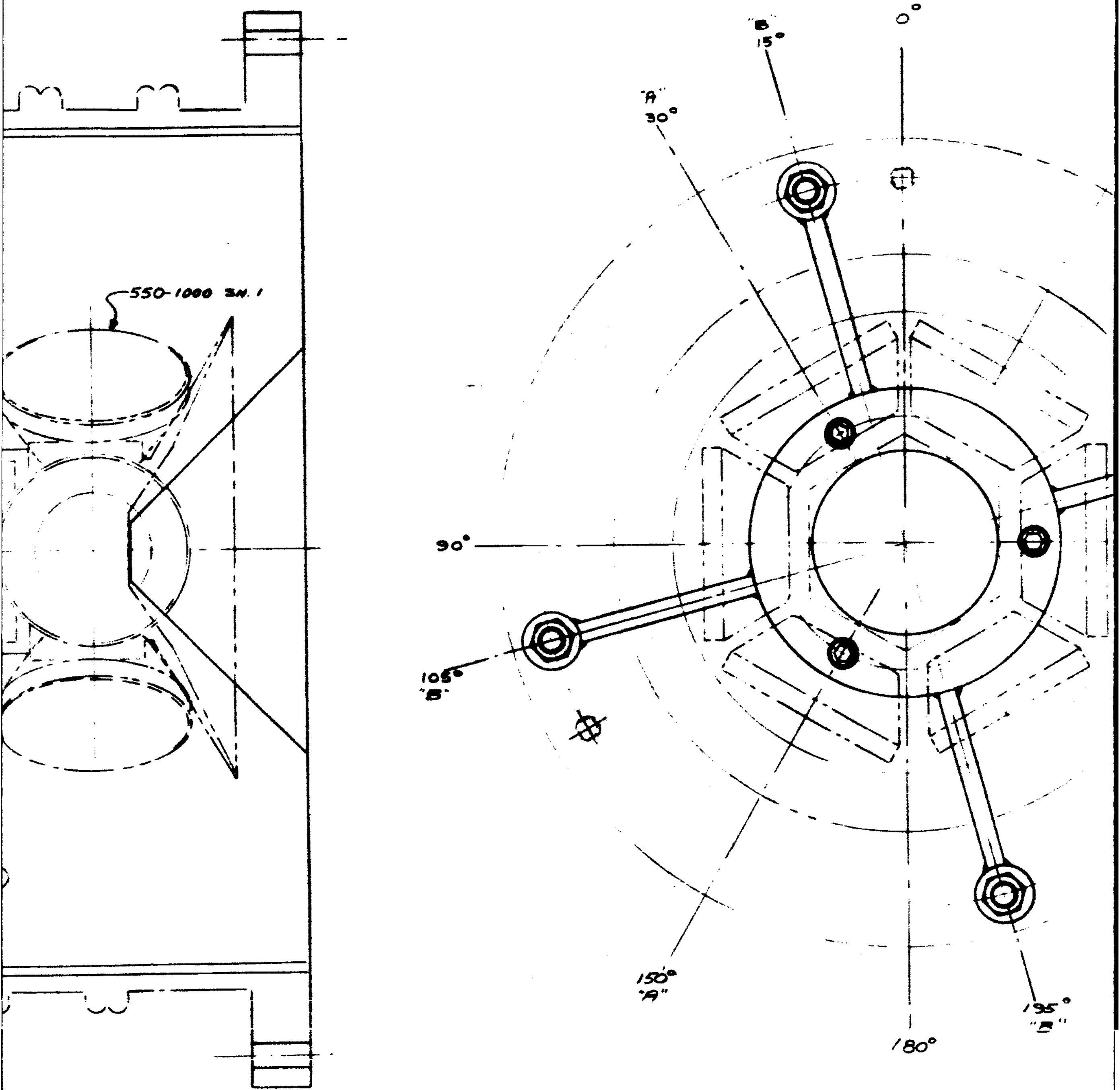

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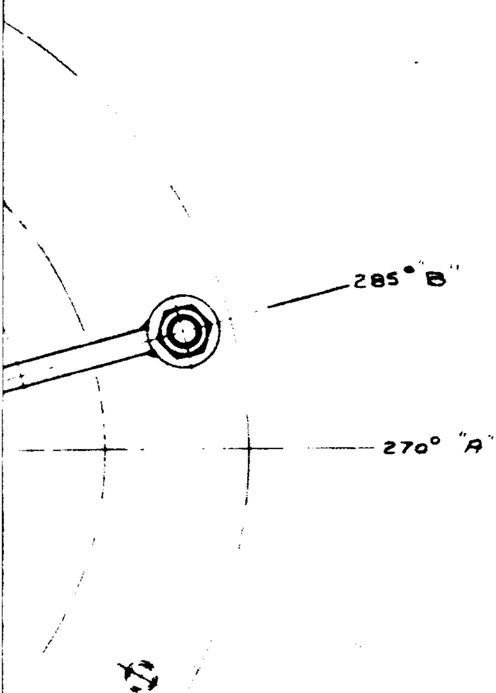


FIGURE 3

7 SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
6 UNK = UNKNOWN   N.D. = NO DRAWING, PROCURE FROM THIS L.D.
5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

DESIGN FINALIZED	DATE	INIT	DATE	INIT	DATE	INIT	DATE	INIT
	[illegible]	[illegible]						

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	Y	Z
1																						
2																						
V																						
II																						
⊥																						
◎																						

#3

PART	SIZE	REV	REQ	MAT'L	NOTES
307	NO		2	S S.	5/16-18 HEX NUT
306			4	S.S.	SUPPORT LEG
305			1	S.S.	SUPPORT RING
304	NO		3	S S	1/4-20 x 1" LNG S.H.C.S.
303			6	Al_2O_3	INSULATOR
302			4	S S	WEB
301			4	S S	WEB BUSHING

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS .010 MAXIMUM
THREADS: CLASS 2
⌀ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ± 0° 5'
2.0-4.0 RAD ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5x1

FINISH

NEXT ASSY

SIMILAR TO

THERMO ELECTRON

DRAWN	CHECKED	ENGINEER
RB	VP	[illegible]

TITLE: SIX CONVERTER GENERATOR (SUPPORT STRUCTURE)

SIZE	DRAWING NUMBER	SHEET	REV
H	550 1000	3	

#d

4

positions has the disadvantage that the cavity area is increased considerably while the effective emitter area is maintained constant; thus, the cavity surface utilization factor* is decreased and the fixed losses of the generator are increased. It is evident then that no advantage is gained by tilting the converters, and, for this reason, the planar layout shown in Figure 1 was adopted.

The compatibility of the converter design selected with generator JG-3 has been established by the fabrication of a number of Series VIII converters that conform with the converter layout shown in Figure 2 (except for the emitter shoe piece and associated shielding), and which have been verified to be compatible with the mounting block of generator JG-3.

To avoid distortion of thermal shields and to avoid the possibility of subsequent electrical shorting, the shield shapes have been made as axisymmetric as possible and shields at different electrical potentials are located in such a manner as to be fully effective and yet incapable of distorting in the directions required to effect an electrical short.

Autonomous generator heat transfer is accomplished with the help of a cylindrical generator radiator which also serves as the generator support. To demonstrate this autonomy, the support structure shown in Figure 3 includes insulating ceramic washers at the generator mounting points.

Other features of the preliminary generator design include:

1. Compatibility with the JPL vacuum test chamber.
2. The attachment of the converters is essentially identical to that used in generator JG-3.

*P. J. Brosens, Solar Thermionic Generators for Space Power, ASME Paper, 64-WA/Sol-1 presented at Winter Annual Meeting, Dec. 1964

3. The front cone affords protection to the seals of all converters in case of misorientation, and this protection is assured even at high front cone temperatures by the use of 5 radiation shields behind it.
4. The emitter shoe pieces of the converters are relatively lightweight, and they permit efficient enclosure of the collected thermal flux within the generator cavity. They can be mounted after converter fabrication by electron beam welding their collar extension to the sides of the emitter of the converter.
5. Considerable thermal shielding for the emitter shoe pieces is provided from the rear of the generator.
6. The shape of the emitter shoe pieces can be produced by conventional milling operations.

1.2 Final Design of 6-Converter Generators

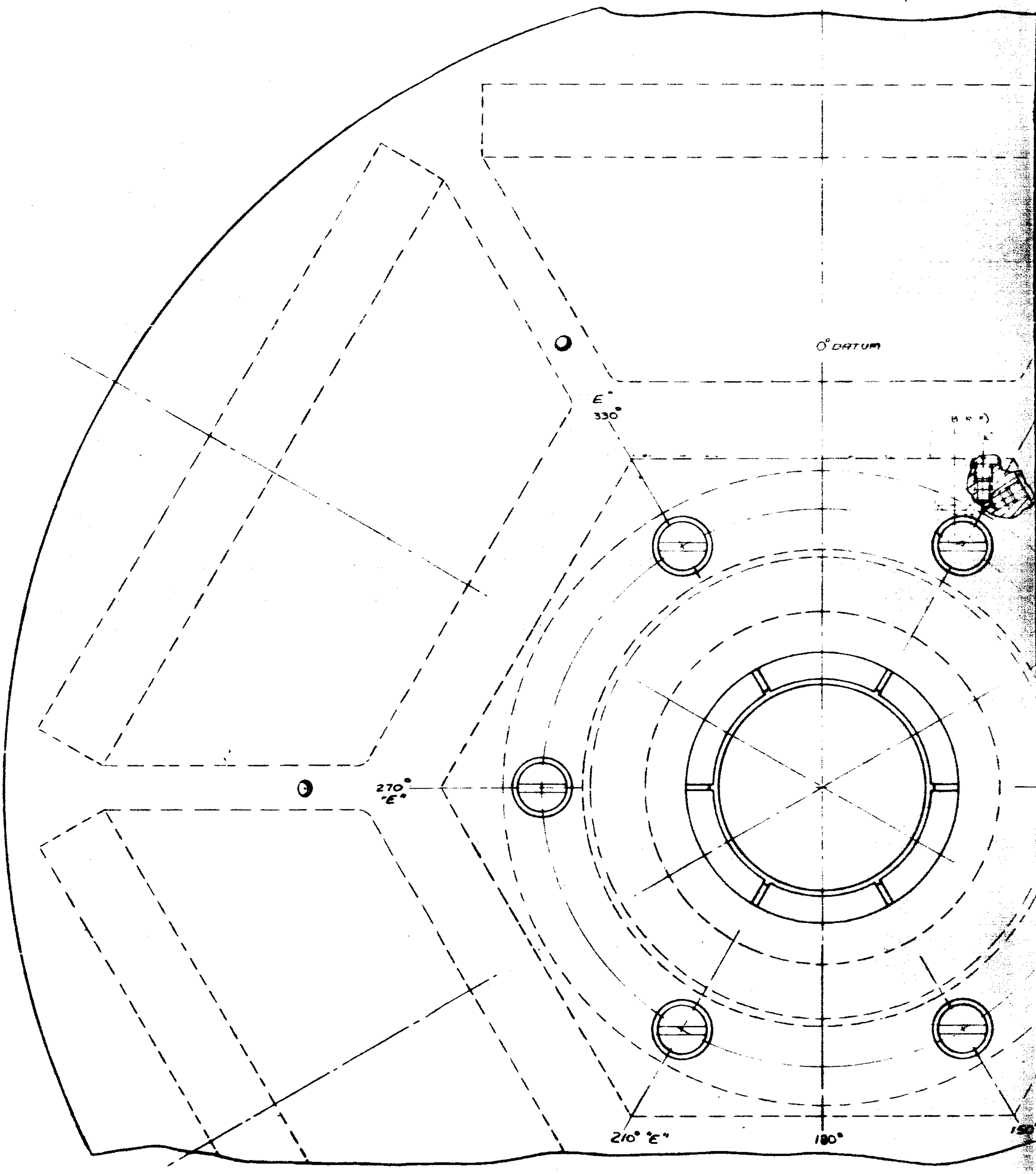
Figures 3a, 3b, and 3c, TEE Dwg. 550-1000 Revision A, Sheets 1, 2 and 3, show the layout of the 6-converter generator as finally approved by the JPL technical cognizant personnel. As may be seen, the final design is identical to the preliminary layout with the following exceptions:

Sheet 1:

Front cone shields: increased in number from 1 to 5 to afford additional protection to the converters from stray radiation. Front cone and rear cavity piece tungsten is the material specified for these parts instead of molybdenum and tantalum, so as to provide greater operating temperature range.

Sheet 2:

Converter shoe piece: electron beam weld is specified as the method of



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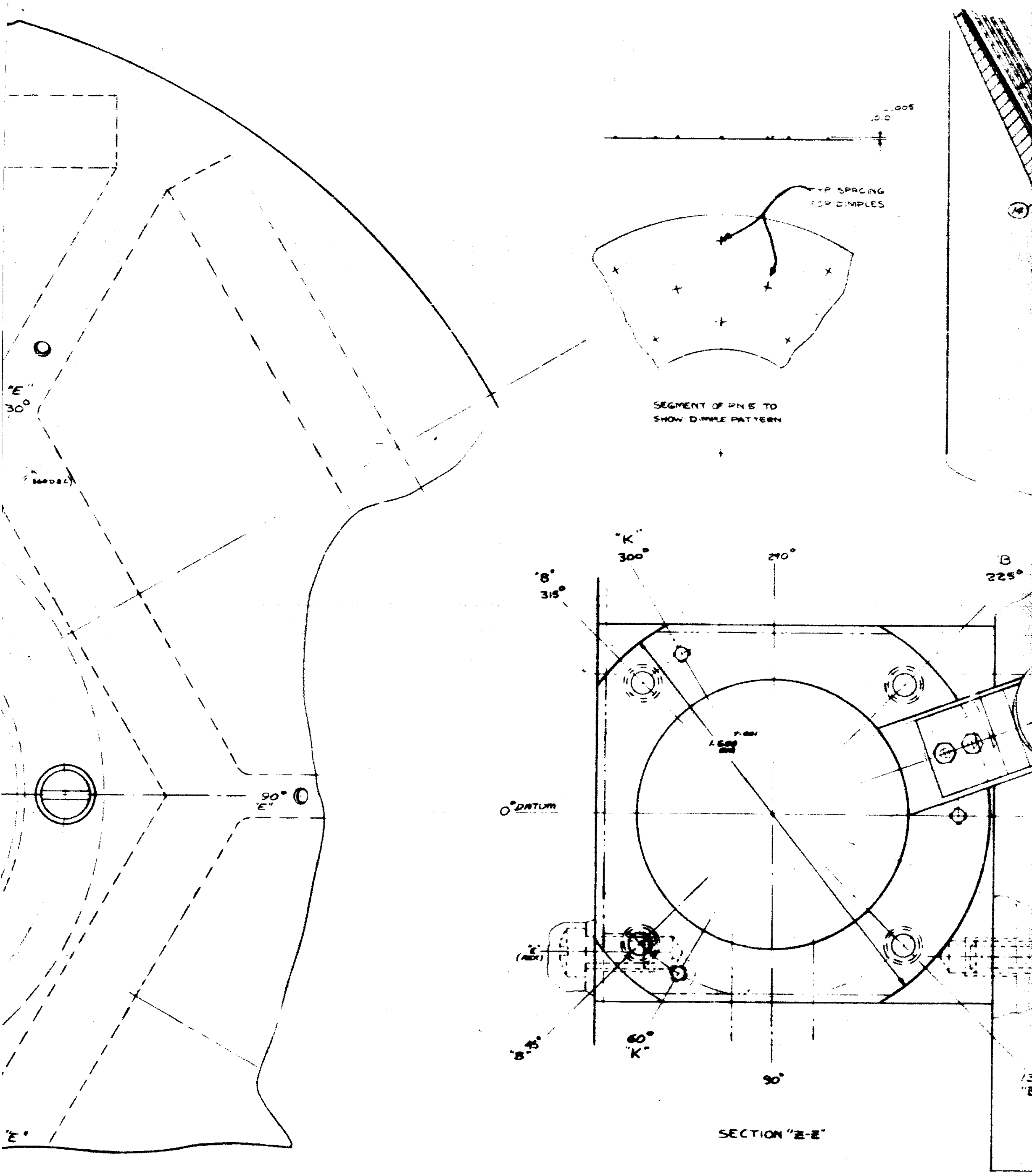
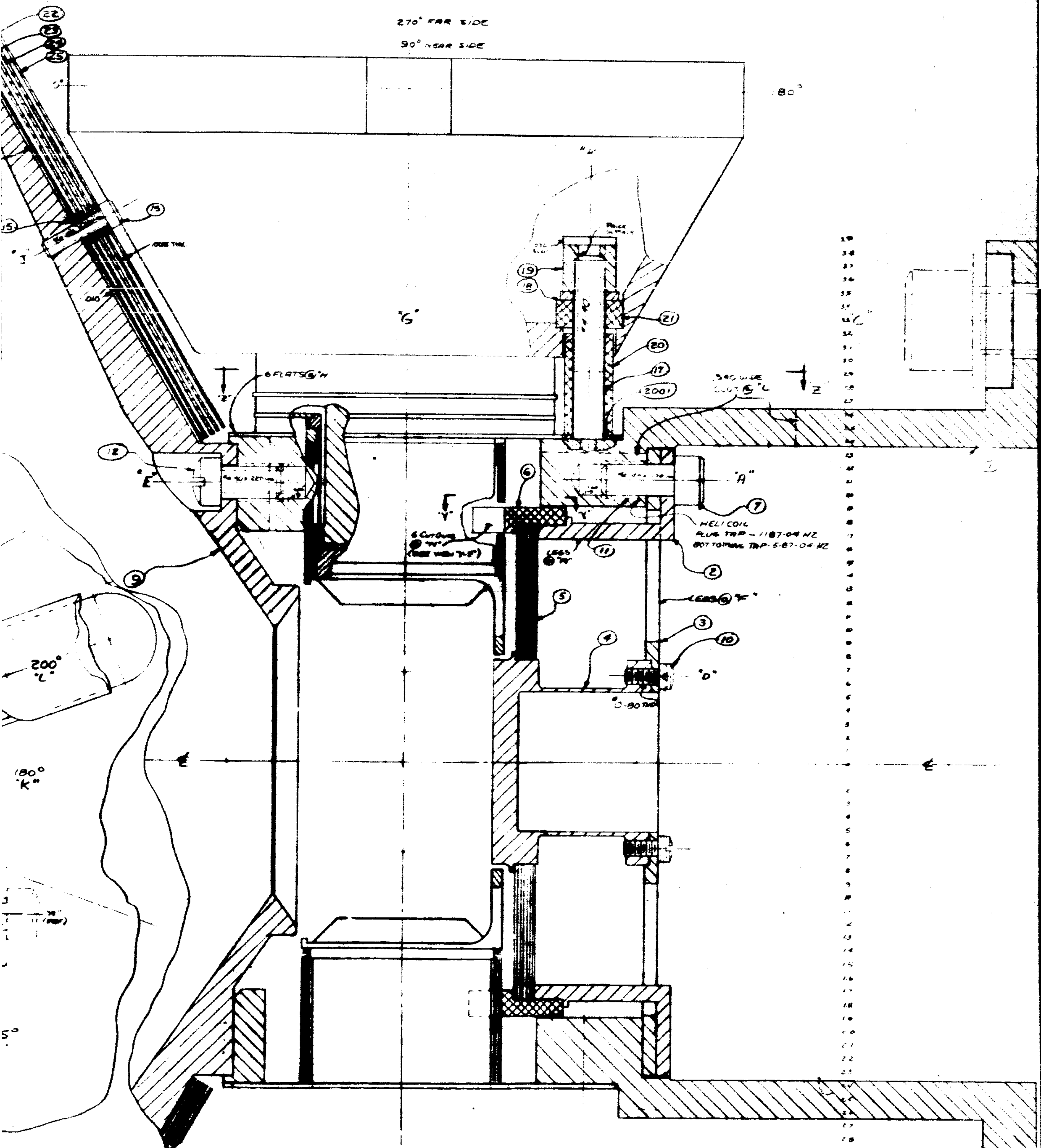
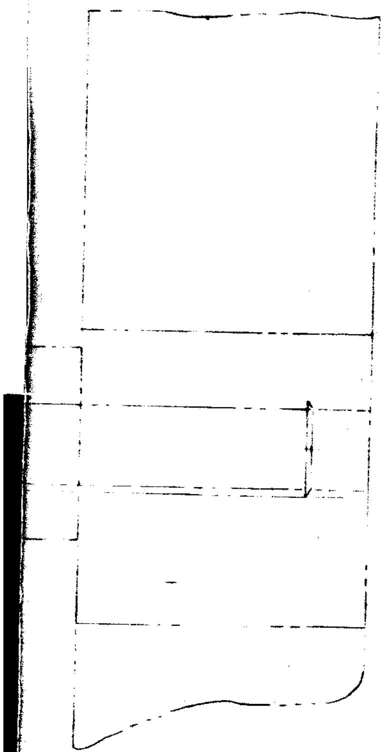
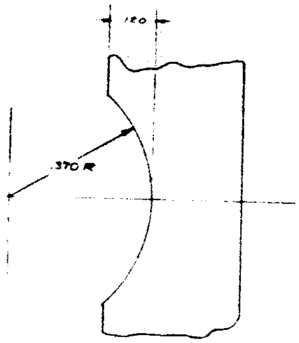

TYP SPACING
FOR DIMPLES
SEGMENT OF PN 5 TO
SHOW DIMPLE PATTERN
"E"
30°
90°
"E"
"E"
"K"
300°
270°
"B"
315°
"B"
225°
0° DATUM
"B" 45°
60°
"K"
90°
SECTION "Z-Z"

#2

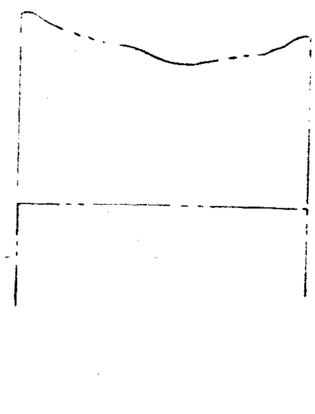

270° FAR SIDE
90° NEAR SIDE
80°
"G"
"A"
"E"
"J"
"D"
200° "L"
180° "K"
HELI COIL
PLUG TAP - 1187-04 NZ
BOTTOMING TAP - 5-87-04-NZ
6 FLATS

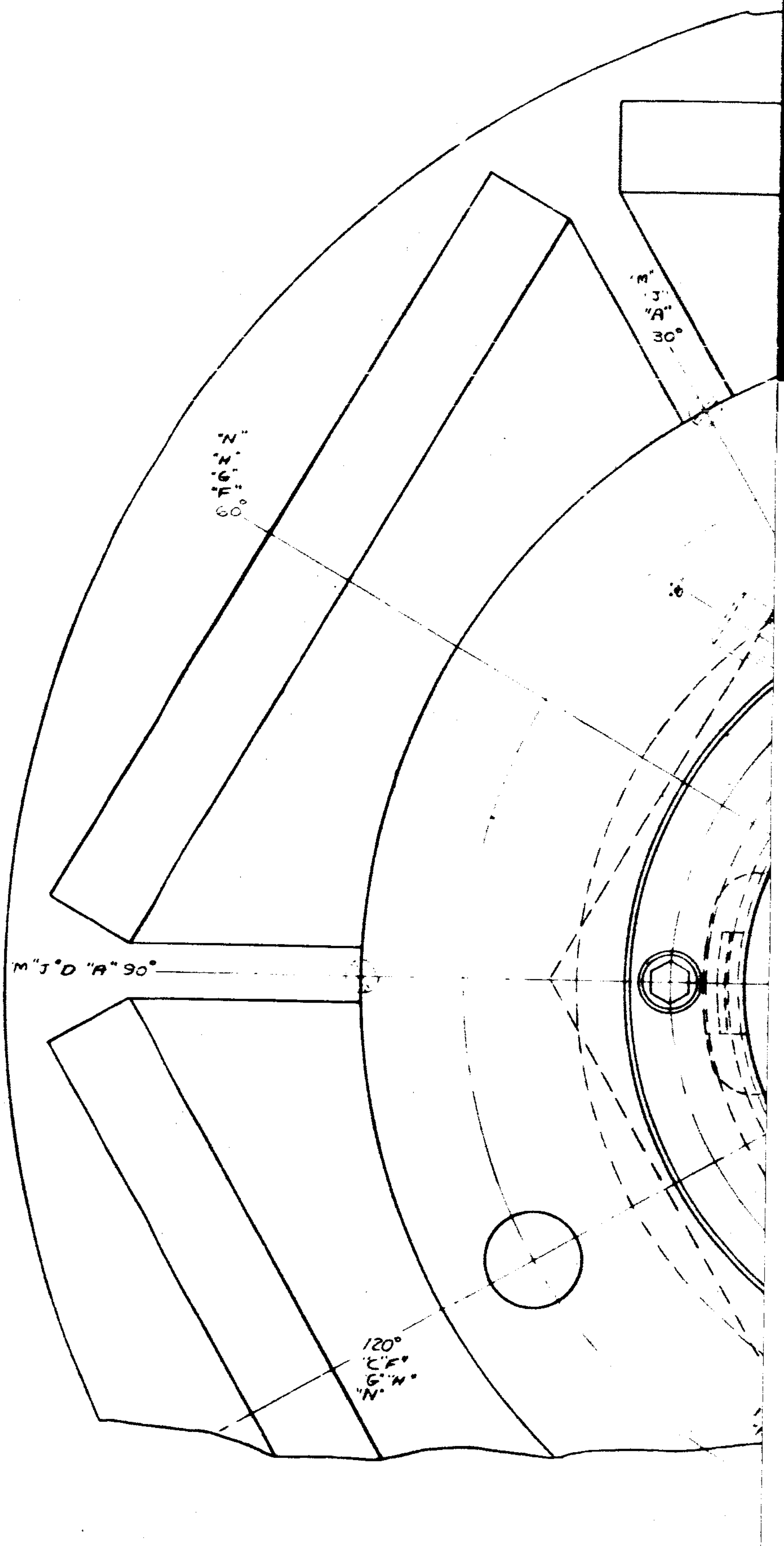
#3





VIEW "Y-Y"
(PN 6 SHOWN ONLY)
TYPICAL CUTOUT @"N"





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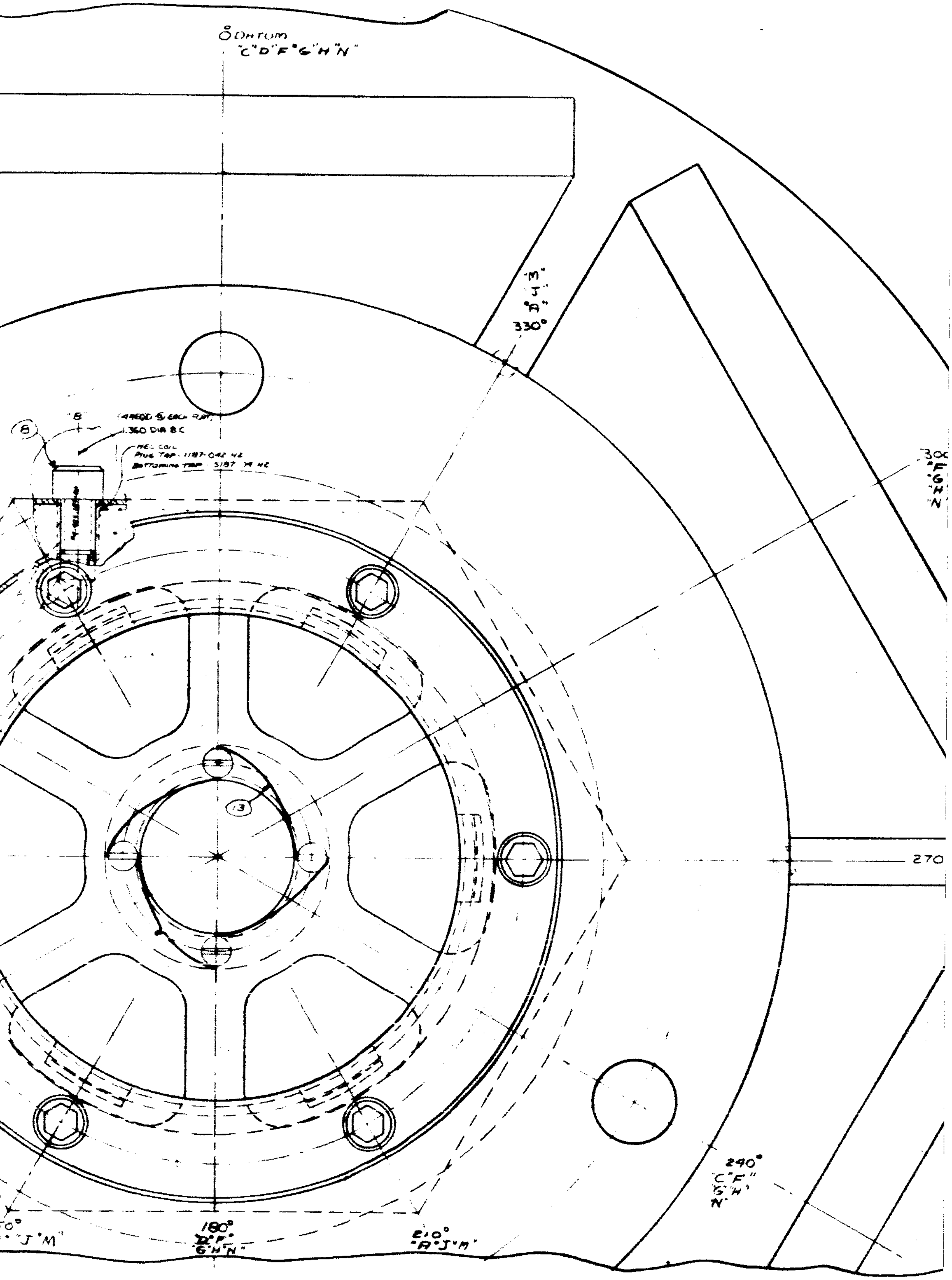


0° DATUM
"C" "D" "F" "G" "H" "N"
"M" "J" "A" 330°
300° "F" "G" "H" "N"
270
240° "C" "F" "G" "H" "N"
210° "A" "J" "M"
180° "D" "F" "G" "H" "N"
"J" "M"
8
"B"
.360 DIA B C
HEL COIL
Plug Tap - 1187-042 HZ
Bottoming Tap - 5187 HZ
13

#5

REV	DESCRIPTION	DATE	BY	APPR
A	SEE OBS. L.O. (8-3-66)	8-10-66	MN	[illegible]

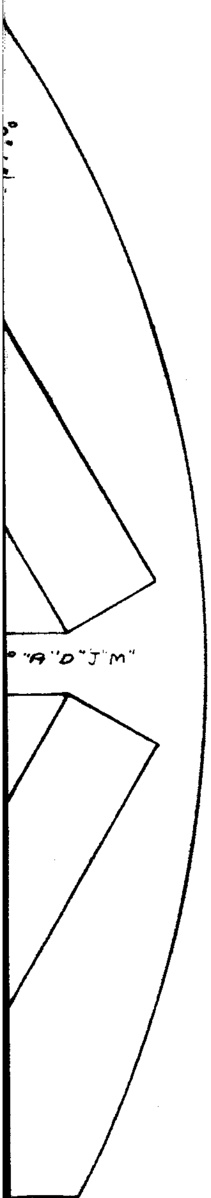


FIGURE 3a

7	SEE FIXTURE LAYOUTS (3000, 3100 ETC.) FOR [illegible] TUBE INFORMATION.
6	UNK = UNKNOWN N.D. = NO DRAWING, PROCURE [illegible] ON THIS L.O.
5	DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4	ALL MATING CORNERS & FILLETS ARE .005 X 45° CHFR. AND .010 R. [illegible]
3	MAX. PERMISSIBLE TAP DRILL DEPTH AND MIN. PERMISSIBLE FULL THREAD DEPTHS ARE SHOWN.
2	SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1	NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

DESIGN FINALIZED	DATE	INIT.	DATE	INIT.	DATE	INIT.	DATE	INIT.

PART	SIZE	REV	REQ	MAT'L	NOTES
					BRAZES
1	A	18		PB130	.002 WASHER
25	B		1	Mo	CONE SHIELD #6
24	B		1	Mo	CONE SHIELD #4
23	B		1	Mo	CONE SHIELD #3
22	B		1	Mo	CONE SHIELD #2
21	A		18	Al_2O_3	SAME AS 479-036 (A)
20	A		18	Al_2O_3	SAME AS 479-058 (A)
19	A		18	S.S	NUT
18	A		18	S.S	WASHER
17	B		18	S.S	STUD
16	ND		6	S.S	#0-80 x .250 LNG S.H.C.S.
15	A		30	Mo	WASHER
14	B		1	Mo	CONE SHIELD #1
13	ND		1	Mo	.020 WIRE
12	A		6	Ta-W	#4-40 x .220 LNG P.H.C.S.
11	ND		36	S.S.	#3985 OPEN .0108 HELI COIL
10	A		4	Ta-W	#0-80 x .125 LNG (SP)
9	D		1	W	FRONT CONE
8	A		24	S.S.	#4-40 x .187 LNG S.H.C.S.
7	A		6	S.S	#4-40 x .375 LNG S.H.C.S.
6	D		1	Al_2O_3	SHIELD INSULATOR
5	C		6	Mo	REAR SHIELD
4	B		1	W	REAR CAVITY PIECE
3	D		1	Nb	REAR CAVITY PIECE SUPPORT
2	D		1	Nb	REAR SHIELD HOLDER
1	D		1	Mo	FRAME

UNLESS OTHERWISE SPECIFIED

DECIMAL .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAXIMUM
THREADS CLASS 2
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP. WITHIN .005 T.I.R.
SURFACES TO BE PAR. WITHIN .005 T.I.R.
HOLE ANGULAR TOL. [illegible]
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 x 1 | FINISH

NEXT ASSY | SIMILAR TO

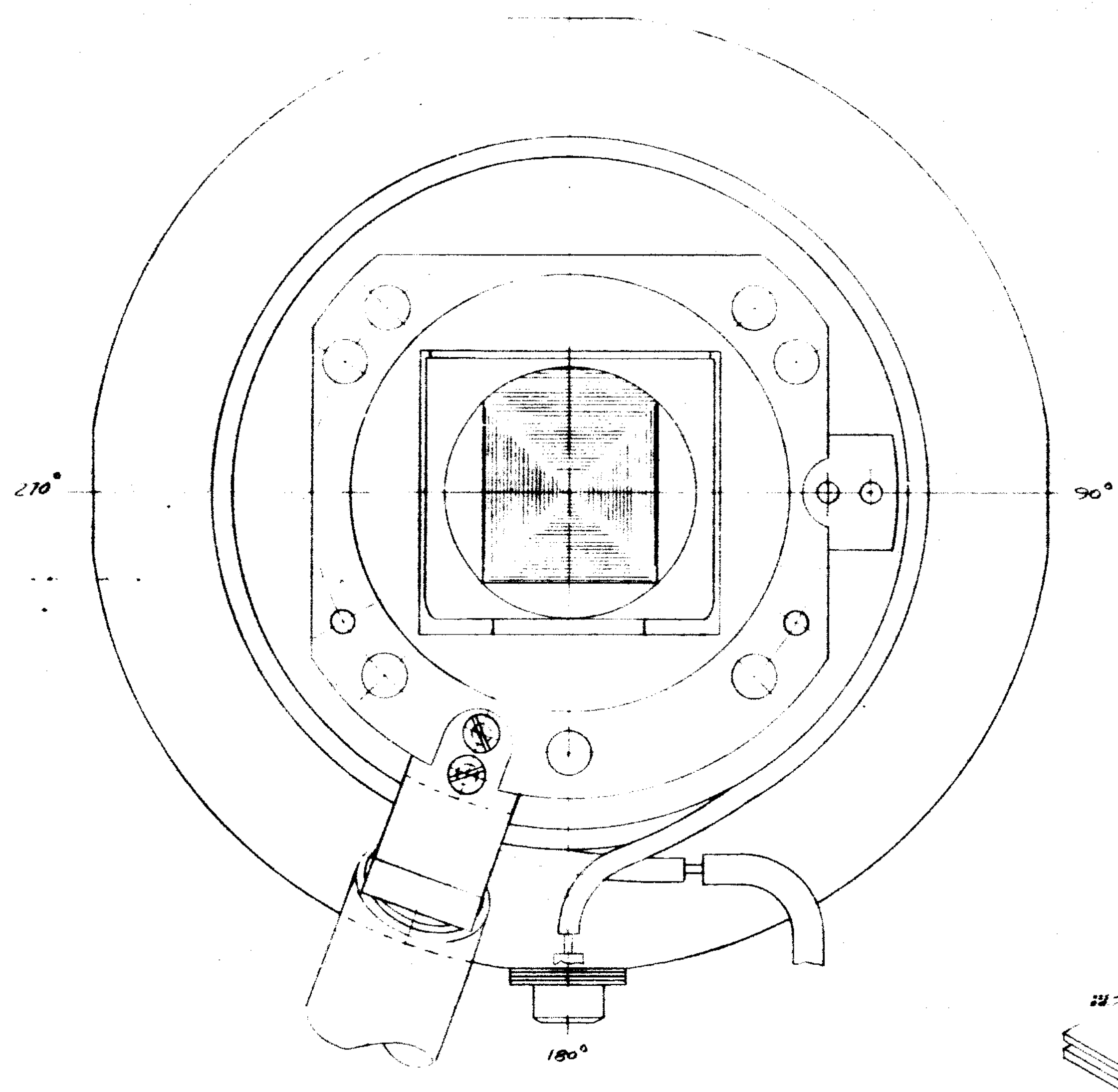
THERMO ELECTRON

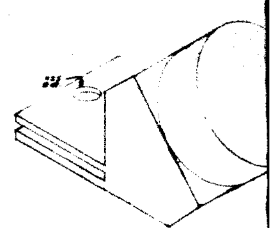
DRAWN	CHECKED	ENGINEER

TITLE: SIX CONVERTER GENERATOR

SIZE	DRAWING NUMBER	SHEET	REV
H	550-1000	1	A

#6

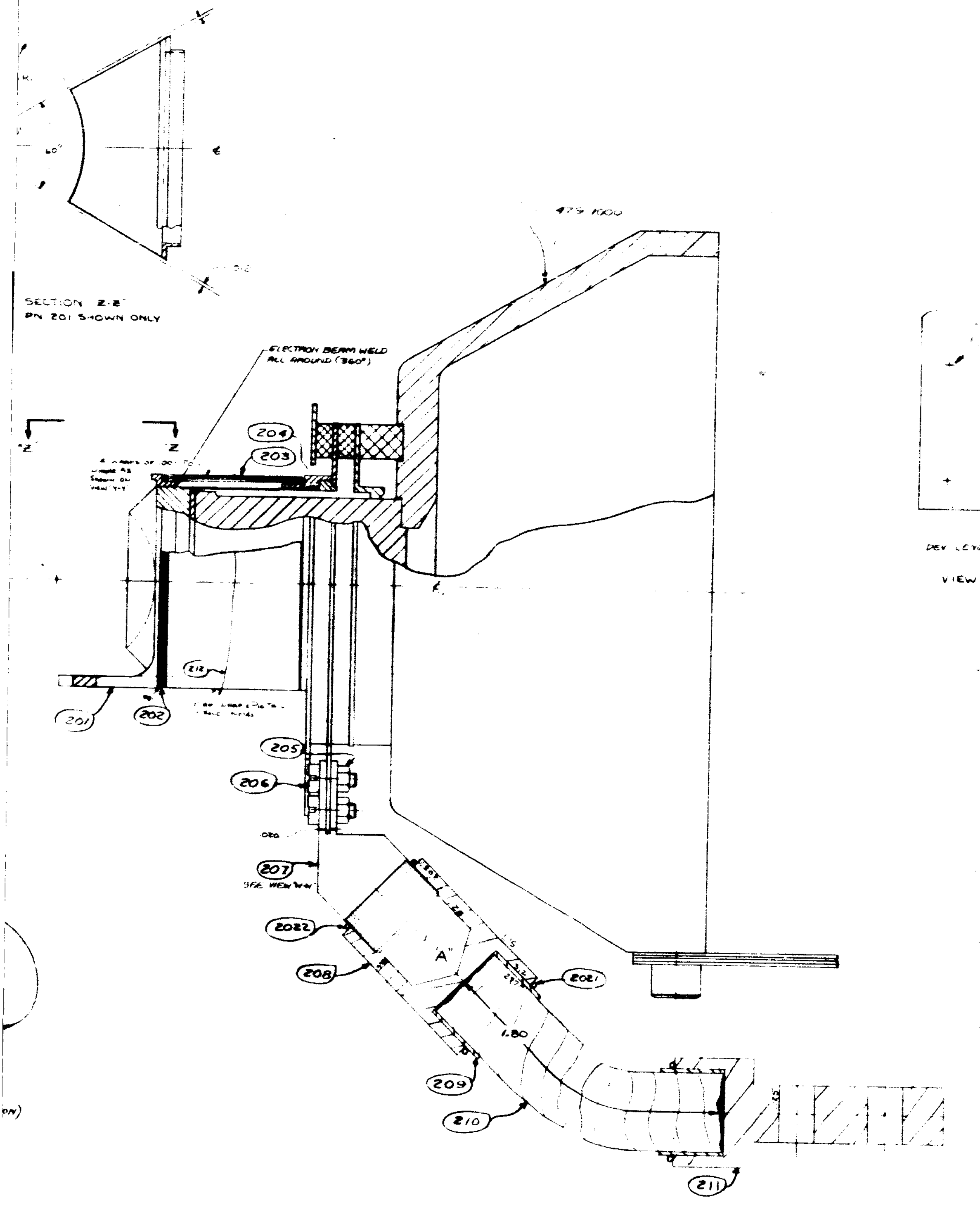




P/N 207
SHOWN FOR CLARIFICAT
VIEW "W-W"

200°
"A"

#1


SECTION Z-Z
PN 201 SHOWN ONLY
ELECTRON BEAM WELD
ALL AROUND (360°)
Z
Z
201
202
203
204
205
206
207
SEE VIEW W-W
2022
208
209
210
211
2021
212
"A"
1.80
VIEW

#2

REV	DESCRIPTION	DATE	BY	APPR
A	SEE DBS [illegible] (8-9-65)	8-10-65	MN	

TYP SPACING

Y-Y

FIGURE 3b

PART	SIZE	REV	REQ	MAT'L	NOTES
					BRAZES
2021	[illegible]		2		
2022	[illegible]		1		
212	ND		AS REQ	Mo	.003 WIRE
211	B		1	Cu	LEAD TERMINAL
210	A		1	Cu	LEAD
209	A		2	[illegible]	LEAD SLEEVE
208	B		1	Cu	LEAD ADAPTER
207	B		1	Nb	LEAD CLAMP
206	ND		2	S.S.	00-96 X [illegible]
205	ND		2	S.S.	00-96 HEX NUT
204	B		1	Ta	SHIELD SUPPORT
203	B		1	Ta	CONVERTER SHIELD (.001 THK)
202	A		5	Ta	SHOE PIECE SHIELD (.001 THK)
201	C		1	Ta	SHOE PIECE

7 SEE FIXTURE LAYOUTS (3000, 3100 ETC.) FOR FIXTURE INFORMATION.
6 UNK = UNKNOWN N.D. = NO DRAWING, PROCURE FROM THIS L.D.
5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3 MAX PERMISSIBLE TAP DRILL DEPTH AND MIN PERMISSIBLE FULL THREAD DEPTHS ARE SHOWN.
2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

DESIGN FINALIZED | DATE | INIT | DATE | INIT | DATE | INIT | DATE | INIT

UNLESS OTHERWISE SPECIFIED

DECIMAL .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAXIMUM
THREADS CLASS 2
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE [illegible] WITHIN .005 T.I.R.
SURFACES TO BE [illegible] WITHIN .005 TIR
HOLE ANGULAR TOL. 0-2.0 RAD ±0° 5'
2.0-4.0 RAD ±0° 3'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE 5 X 1 | FINISH

NEXT ASSY | SIMILAR TO

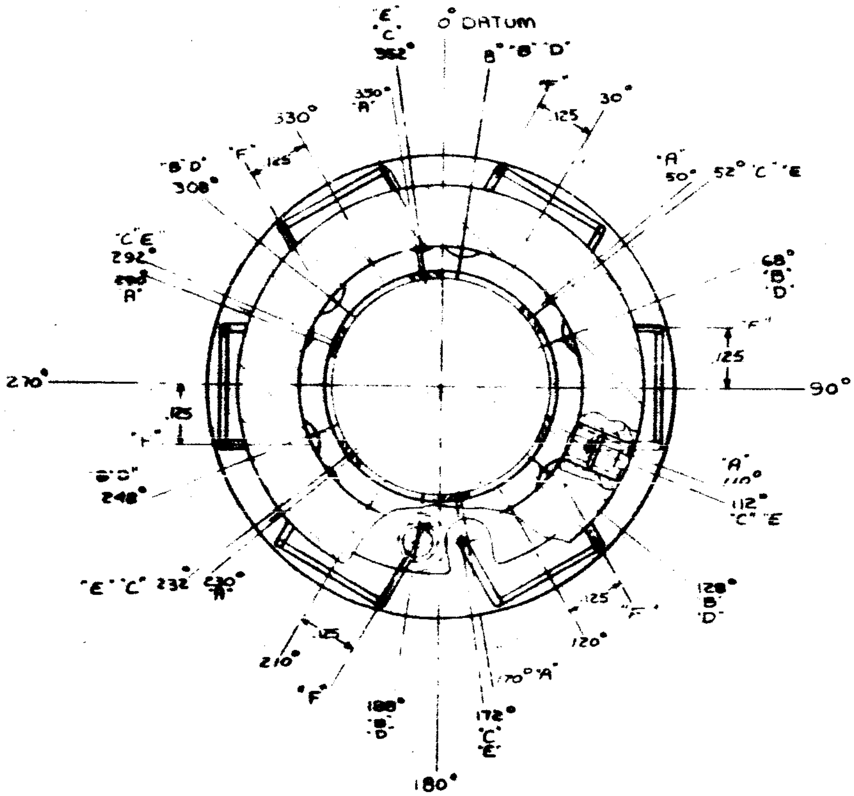
THERMO ELECTRON

DRAWN | CHECKED | ENGINEER

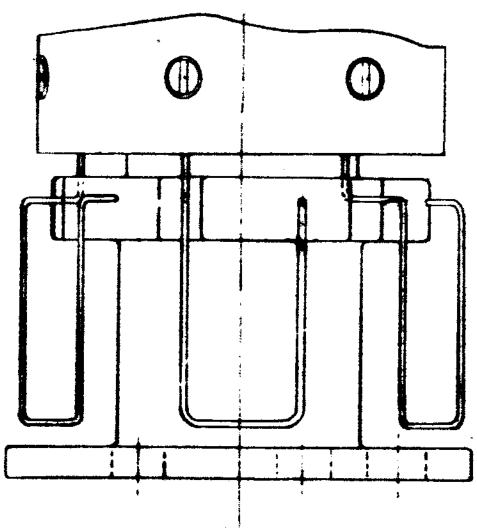
TITLE
SIX CONVERTER
GENERATOR CONVERTER

SIZE | DRAWING NUMBER | SHEET | REV
H | 550-1000 | 2 | 4

#3

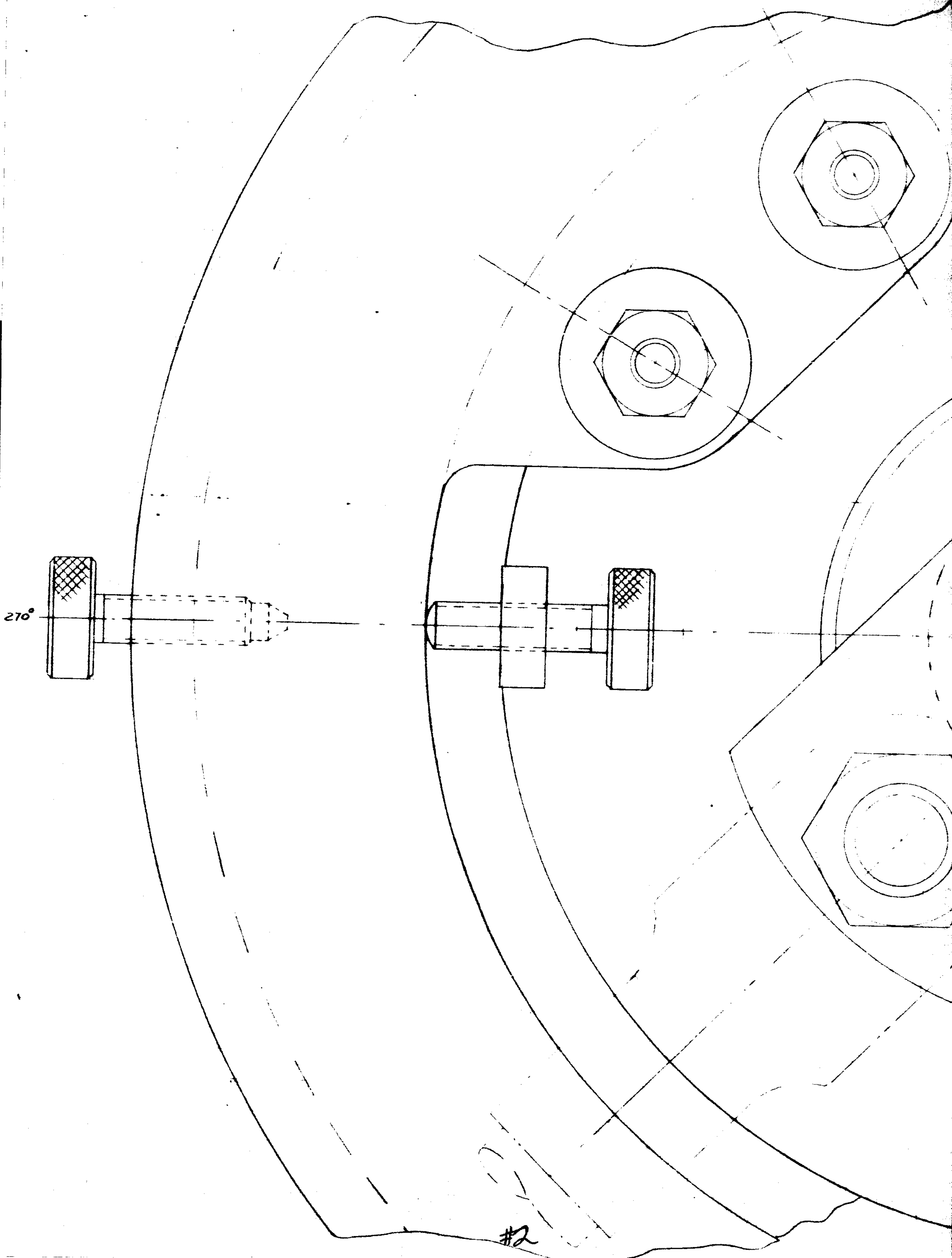


SECTION "Z-Z"

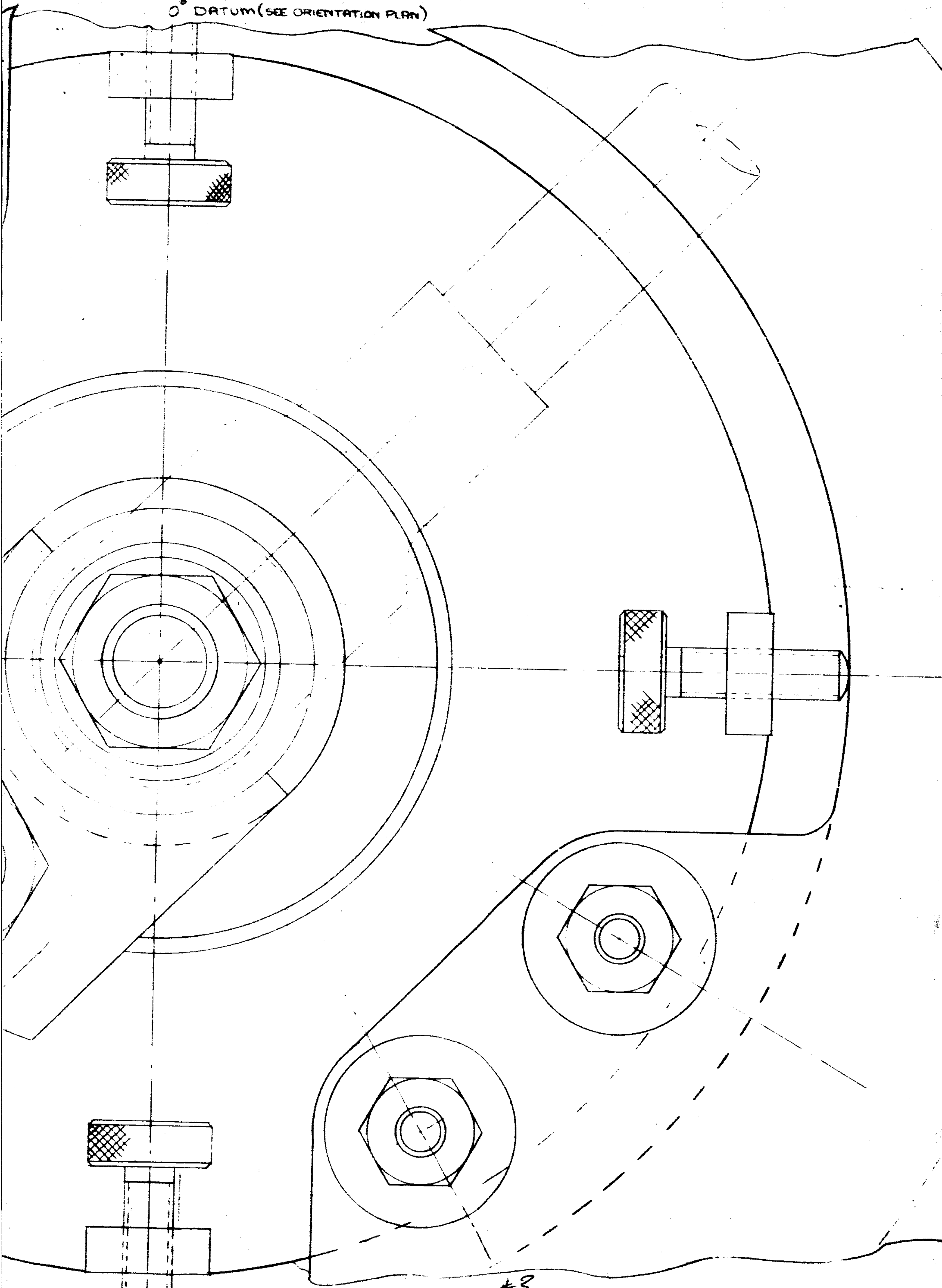


SECTION "Y-Y"

#7



270°
#2



#3

attaching the shoe piece to the converter structure.

Sheet 3:

Frame mounting: the "B" holes of the generator extension frame (parts No. 301-302-305) have been enlarged to allow lateral adjustment of the generator position inside the vacuum test chamber.

1.3 Cavity Heat Balance

1.3.1 Assumed Cavity Geometry

For the purpose of conducting a flux distribution analysis, the generator cavity geometry is simplified so that a moderate number of parameters, namely 10, of which 7 are independent, can describe it. The simplified geometry is shown in Figure 4, and, as is immediately apparent, it approaches very closely the actual cavity configuration. The major differences are:

1. Cavity interstitial spaces are lumped with cavity areas and treated analytically as sharing common average absorptivity and emissivity properties. Thus, the values of emissivity and absorptivity which are specifically assumed for the various cavity surfaces must take into account the fact that they include the properties of these interstitial spaces.
2. The shoe pieces of the converters are assumed to form a cylindrical surface of radius R5.
3. The faces of the converters are assumed to be flat and circular with radius R6.
4. The extensions of the shoe pieces which form the bottom of the cavity are divided into 3 finite elements operating at three corresponding discrete temperature levels.

The emissivity and absorptivity values for each of the defined cavity surface elements can of course be individually assigned arbitrarily.

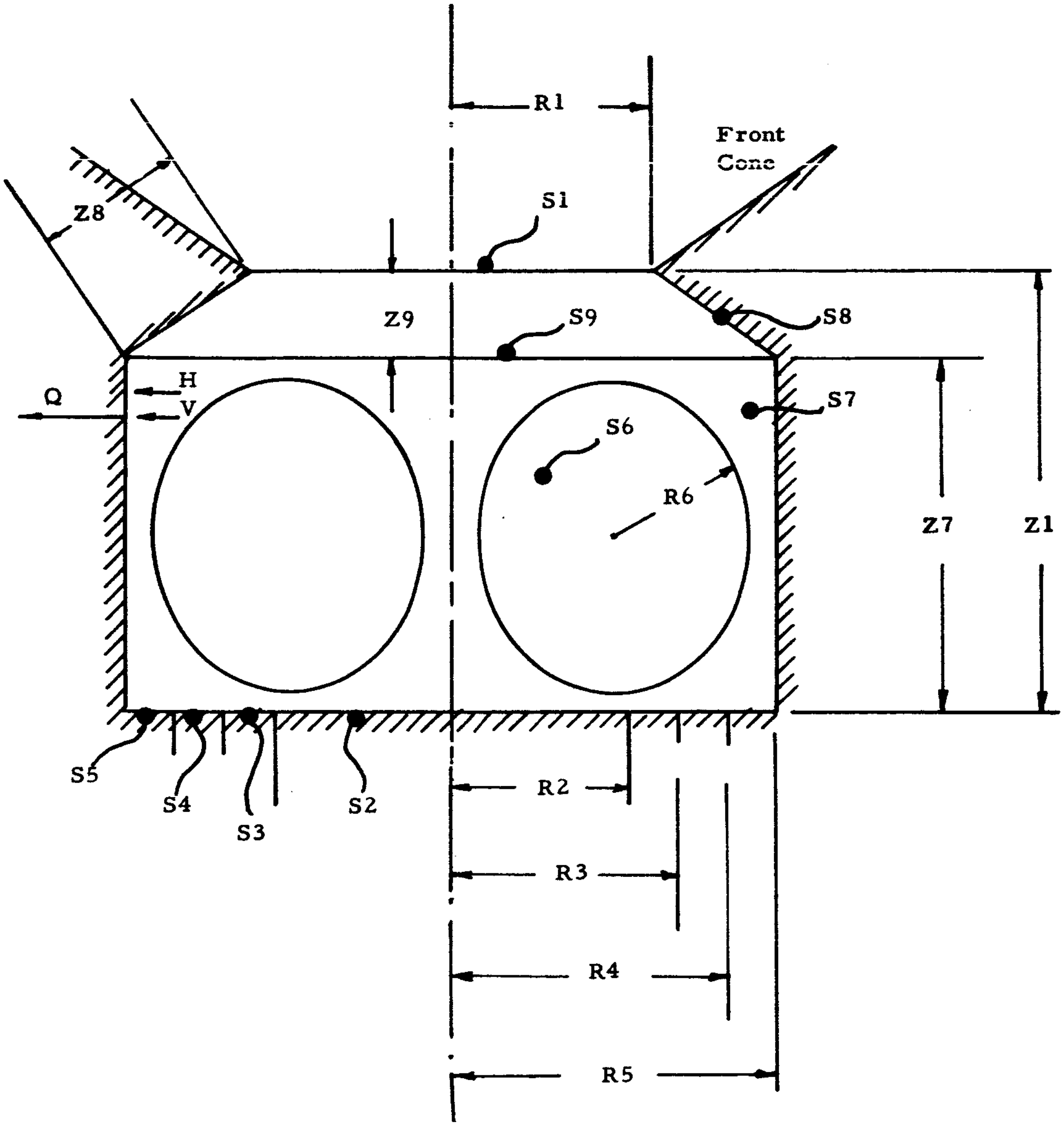


Figure 4. Assumed Generator Cavity Geometry

1.3.2 Input Solar Flux Distribution

One of the required data for the computation of the solar flux in a thermionic generator cavity is the actual amount of solar radiation that reaches the individual cavity elements considered in the analysis.

Since most cavity elements are reasonably removed from the focal plane, they will essentially "see" the arriving solar flux as though it had originated at a pseudo point source P on the optical axis, as shown in Figure 5, and with a specified polar distribution of intensity comprised between the rim angle θ_1 of the concentrator and a shadow angle θ_s produced by the generator and its test chamber on the solar concentrator.

Although the intensity produced by an ideal paraboloid increases slightly with θ, the fact that profile errors also increase with θ in actual concentrators has led to the assumption in this analysis that the solar flux is spread spherically with uniform intensity between the angles θ_s and θ_1 from a pseudo point source P, as shown in Figure 5.

The fraction Fi of solar flux reaching each cavity element is then strictly proportional to the value of the solid angle it intercepts as viewed from the pseudo point source P.

For the given data $\theta_1 = 55^o$ and $D_m = 9.5$ ft., the focal length computed from the formula:

$$f = (1 + \cos \theta_1) D_m / 4 \sin \theta_1$$

is 54.8 in.

The shadow angle θ_s has been computed assuming a vacuum chamber effective radius of 12.8 in.:

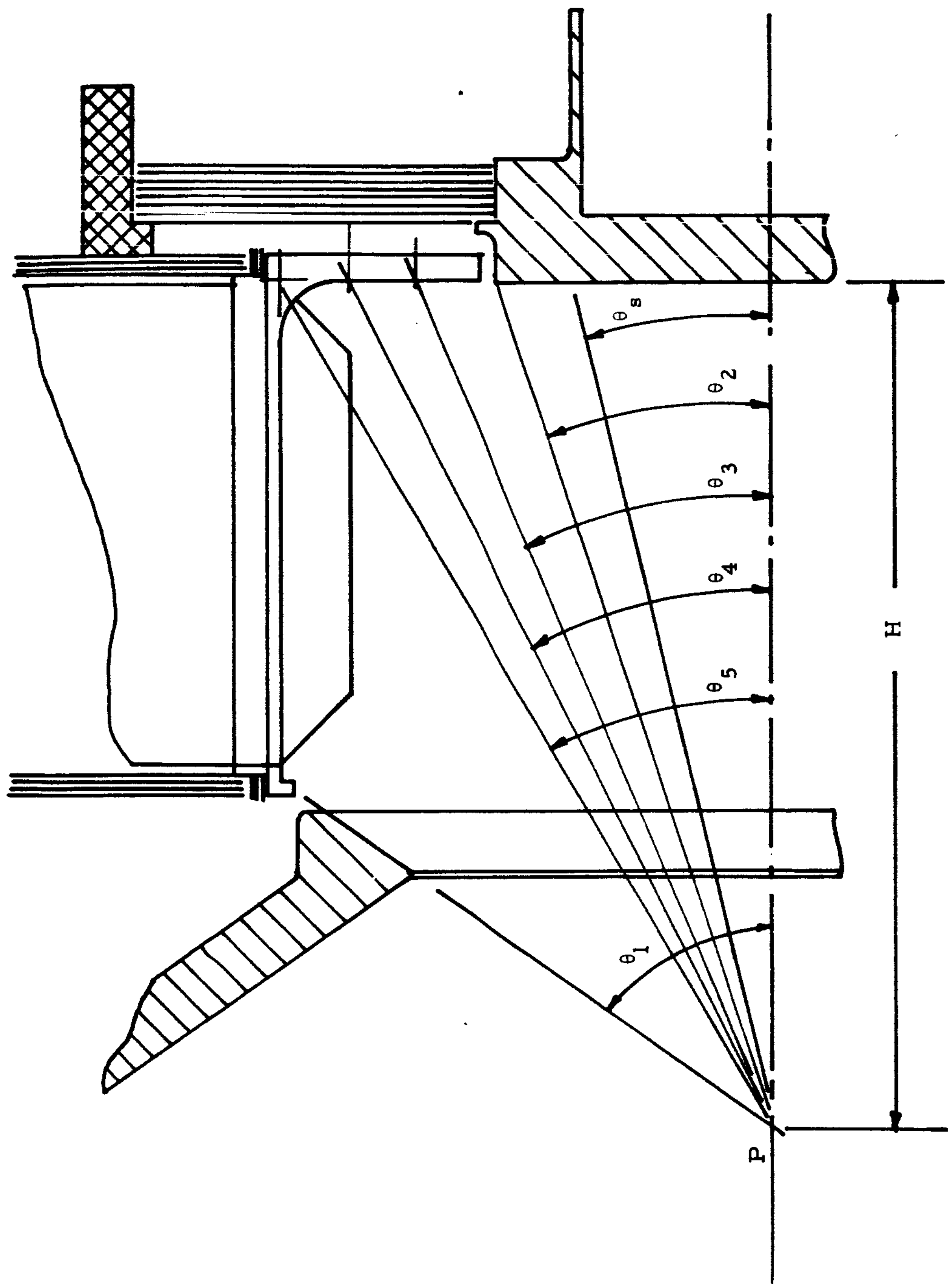


Figure 5. Idealized Input Solar Flux Pattern

$$\tan \theta_s = 12.8/54.8 = .2338$$
$$\theta_s = 13^\circ\ 10'$$

The value of the other angles appearing in Figure 5 are calculated as follows:

$$\theta_2 = \tan^{-1}(R2/H) = \tan^{-1}(.97/2.95) = 18^\circ\ 11'$$
$$\theta_3 = \tan^{-1}(R3/H) = \tan^{-1}(1.22/2.95) = 22^\circ\ 27'$$
$$\theta_4 = \tan^{-1}(R4/H) = \tan^{-1}(1.47/2.95) = 26^\circ\ 30'$$
$$\theta_5 = \tan^{-1}(R5/H) = \tan^{-1}(1.72/2.95) = 30^\circ\ 13'$$

The solid angle comprised between θ_s and θ_1 is:

$$\psi = 2\pi\,(\cos\theta_s - \cos\theta_1)$$

The energy per steradian is therefore:

$$w = \frac{W}{2\pi\,(\cos\theta_s - \cos\theta_1)}$$

For a surface intercepting a solid angle ψ_i, the corresponding energy is then:

$$W(i) = \frac{W\psi_i}{2\pi\,(\cos\theta_s - \cos\theta_1)}$$

and the corresponding value of the energy fraction F(i) is:

$$F(i) = \frac{W(i)}{W} = \frac{\psi_i}{2\pi\,(\cos\theta_s - \cos\theta_1)}$$

For the various cavity surfaces, the values of F are:

$$F1 = .0000$$
$$F2 = (\cos\theta_s - \cos\theta_2)/(\cos\theta_s - \cos\theta_1)$$
$$F3 = (\cos\theta_2 - \cos\theta_3)/(\cos\theta_s - \cos\theta_1)$$

$$F4 = (\cos\theta_3 - \cos\theta_4)/(\cos\theta_s - \cos\theta_1)$$

$$F5 = (\cos\theta_4 - \cos\theta_5)/(\cos\theta_s - \cos\theta_1)$$

$$F6 = (S6)(\cos\theta_5 - \cos\theta_1)/(S6 + S7)(\cos\theta_s - \cos\theta_1)$$

$$F7 = (S7)(\cos\theta_5 - \cos\theta_1)/(S6 + S7)(\cos\theta_s - \cos\theta_1)$$

$$F8 = .0000$$

For the values of θ given:

$\cos\theta_s = .9737$

$\cos\theta_1 = .5735$

$\cos\theta_2 = .9500$

$\cos\theta_3 = .9242$

$\cos\theta_4 = .8949$

$\cos\theta_5 = .8641$

For:

R6 = .84 cm

R5 = 1.72 cm

Z7 = 1.73 cm

S6* = 13.3 cm^2

S6 + S7 = 18.7 cm^2

S7 = 5.4 cm^2

---

* $S6 = 6\pi(R6)^2$
$S7 = 2\pi(R5)(Z7) - S6$

and:

$$S6/(S6 + S7) = .711$$

$$S7/(S6 + S7) = .289$$

The calculated values of energy fractions are then:

F1	=	.0000
F2	=	.0591
F3	=	.0645
F4	=	.0732
F5	=	.0770
F6	=	.5162
F7	=	.2100
F8	=	.0000

1.3.3 <u>View Factor Derivation</u>

To derive the view factors between the various area elements defined for the generator cavity in Figure 4, three basic relationships were used:

1. The sum of the view factors from any one surface to all other surfaces including itself is unity.
2. For any pair of elements, the products of area times the view factor to the other area are equal.
3. For two discs having a common axis of symmetry, the view factor from one to the other is given by the expression:*

$$F_{12} = (Y_{12}/2) \left(1 - \sqrt{1 - (2 R_2/R_1 Y)^2}\right)$$

where R_1 and R_2 are the respective radii and Y is an intermediate function defined in terms of the distance Z between the discs by:

$$Y_{12} = 1 + (Z/R_1)^2 + (R_2/R_1)^2$$

*Ref. NACA TN 2836, December 1952, Radiant-Interchange Configuration Factors, D. C. Hamilton and W. R. Morgan

The resulting equations for the evaluation of all view factors are given below in FORTRAN notation where:

- . denotes a floating point constant
- / denotes a division
- * denotes a multiplication
- ** denotes exponentiation to the constant following the symbol

and where the cavity areas S1, S2 . . . S9 are given by:

```
S1  =  π *R1 **2
S2  =  π *R2 **2
S3  =  π *R3 **2 - S2
S4  =  π *R4 **2 - S3 - S2
S5  =  π *R5 **2 - S4 - S3 - S2
S6  =  6. *π *R6 **2
S7  =  2. *π *R5 * Z7 - S6
S8  =  π (R1 + R5)* Z8
S9  =  π *R5**2
```

View Factor Equations:

```
F11  =  0.
Y12  =  1.+(Z1/R1)**2+(R2/R1) **2
F12  =  0.5 * Y12 *(1. -(1.-(2. +(R2/R1)/Y12)**2)**0.5)
Y13  =  1. + (Z1/R1) ** 2+(R3/R1) **2
F13  =  0.5 *Y13 *(1. -(1. -(2. *(R3/R1)/Y13) **2) **0.5)-F12
Y14  =  1.+(Z1/R1)**2+(R4/R1)**2
F14  =  0.5 *Y14*(1.-(1.-(2.*(R4/R1)/Y14)**2)**0.5)-F12 -F13
Y15  =  1.+(Z1/R1)**2+(R5/R1)
F15  =  0.5*Y15*(1.-(1.-(2.*(R5/R1)/Y15)**2)**0.5)-F12-F13-F14
```

```
Y19   =  1.+(Z9/R1)**2+(R5/R1)**2
F19   =  0.5*Y19 *(1.-(1.-(2.*(R5/R1)/Y19)**2)**0.5)
F18   =  1.-F19
F17   =  (S7/(S7+S6))*(1.-F12-F13-F14-F15-F18)
F16   =  (S6/S7)*F17
F21   =  *S1/S2)*F12
F22   =  0.
F23   =  0.
F24   =  0.
F25   =  0.
Y29   =  1.+ (Z7/R2)** 2+  (R5/R2) ** 2
F29   =  0.5 * Y29 *(1.  -(1.  -(2.*(R5/R2)/Y29)**2)**0.5)
F26   =  (S6/(S6+S7))*(1.  -F29)
F27   =  (S7/S6)*F26
F28   =  1.-F21-F26-F27
F31   =  (S1/S3)*F13
F32   =  0.
F33   =  0.
F34   =  0.
F35   =  0.
F92   =  (S2/S9)*F29
Y93   =  1.+(Z7/R5)**2+(R3/R5)**2
F93   =  0.5*Y93*(1.-(1.-2.*(R3/R5)/Y93)**2)**0.5)-F92
F39   =  (S9/S3)*F93
F36   =  (S6/(S6+S7))*(1.  - F39)
F37   =  (S7/S6)*F36
F38   =  1.-F31-F36-F37
```

```
F41  =  (S1/S4)*F14
F42  =  0.
F43  =  0.
F44  =  0.
F45  =  0.
Y94  =  1.+(Z7/R5)** 2+ (R4/R5) **2
F94  =  0.5 * Y94 * (1.-(1.-(2. *(R4/R5)/Y94)**2)**0.5)-F92-F93
F49  =  (S9/S4)*F94
F46  =  (S6/S6 + S7))* (1.-F49)
F47  =  (S7/S6) * F46
F48  =  1. -F41-F46-F47
F51  =  (S1/S5)*F15
F52  =  0.
F53  =  0.
F54  =  0.
F55  =  0.
Y95  =  2.+ (Z7/R5)**2
F95  =  0.5*Y95*(1.-(1.-(2./Y95)**2)**0.5)-F92-F-93-F94
F59  =  (S9/S5)* F95
F56  =  (S6/(S6+ S7))*(1.-F59)
F57  =  (S7/S6)*F56
F58  =  1.-F51-F56-F57
F61  =  (S1/S6)*F16
F62  =  (S2/S6) *F26
F63  =  (S3/S6)*F36
F64  =  (S4/S6)*F46
F65  =  (S5/S6)*F56
```

$$F96 = (S6/(S6 + S7))*(1. - F92 - F93 - F94 - F95)$$
$$F69 = (S9/S6)*F96$$
$$F66 = (S6/(S6 + S7))*(1. - F62 - F63 - F64 - F65 - F69)$$
$$F67 = (S7/S6)*F66$$
$$F68 = 1. - F61 - F62 - F63 - F64 - F65 - F66 - F67$$
$$F71 = F61$$
$$F72 = F62$$
$$F73 = F63$$
$$F74 = F64$$
$$F75 = F65$$
$$F76 = F66$$
$$F77 = F67$$
$$F78 = F68$$
$$F81 = (S1/S8)*F18$$
$$F82 = (S2/S8)*F28$$
$$F83 = (S3/S8)*F38$$
$$F84 = (S4/S8)*F48$$
$$F85 = (S5/S8)*F58$$
$$F86 = (S6/S8)*F68$$
$$F87 = (S7/S8)*F78$$
$$F88 = 1. - F81 - F82 - F83 - F84 - F85 - F86 - F87$$

1.3.4 Heat Balance Equations

Each cavity surface i receives directly a solar input Wi, the fraction Fi of the total solar input W:

$$Wi = Fi * Wi \qquad (1)$$

and it thermally radiates a flux per unit area:

$$Ei * Pi \qquad (2)$$

where: $Pi = SIGMA * Ti ** 4$ (3)

and: $SIGMA = 5.679 E - 12$ (E = exponentiation)

If we denote by Vi and Hi the total thermal and solar fluxes arriving at each area i, the following matrix equations describe the cavity heat balance:

$$[Eij] * [Hi] = [Pii] \quad (4)$$

and

$$[Aij] * [Vi] = [Wi] \quad (5)$$

where

$$[Pii] = [Fij] * [Ei * Pi * Si] \quad (6)$$

$$Eij = -Fij * (1. - Ei) \text{ for } i \neq j \quad (7)$$

$$Eij = 1-(1. - Ei) * Fii \text{ for } i = j \quad (8)$$

and Aij is obtained using the expressions for Eij and substituting Ai for Ei

The net heat input at each surface is then:

$$Qi = Ei * (Hi - Si * Pi) + Ai * Vi \quad (9)$$

1.3.5 Finite Difference Equations for Shoe Pieces

In the previous section, it is assumed that all cavity temperatures are known (viz. Eq. 3). This is actually not the case, for the temperature distribution in the shoe piece elements S3, S4, S5 and S7 shown in Figure 6 will actually depend on the amount of heat received by these elements which in turn depends on their temperature. The governing equations are as follows:

$$Q3 = C34 * (T3 - T4) + S3 * P3 * B \quad (10)$$

$$Q4 = C45 * (T4 - T5) + S4 * P4 * B - C34 * (T3-T4) \quad (11)$$

$$Q5 = C57 * (T5-T7) + S5 * P5 * B - C45 * (T4-T5) \quad (12)$$

$$Q7 = C76 * (T7-T6) + S7 * P7 * B - C57 * (T5-T7) \quad (13)$$

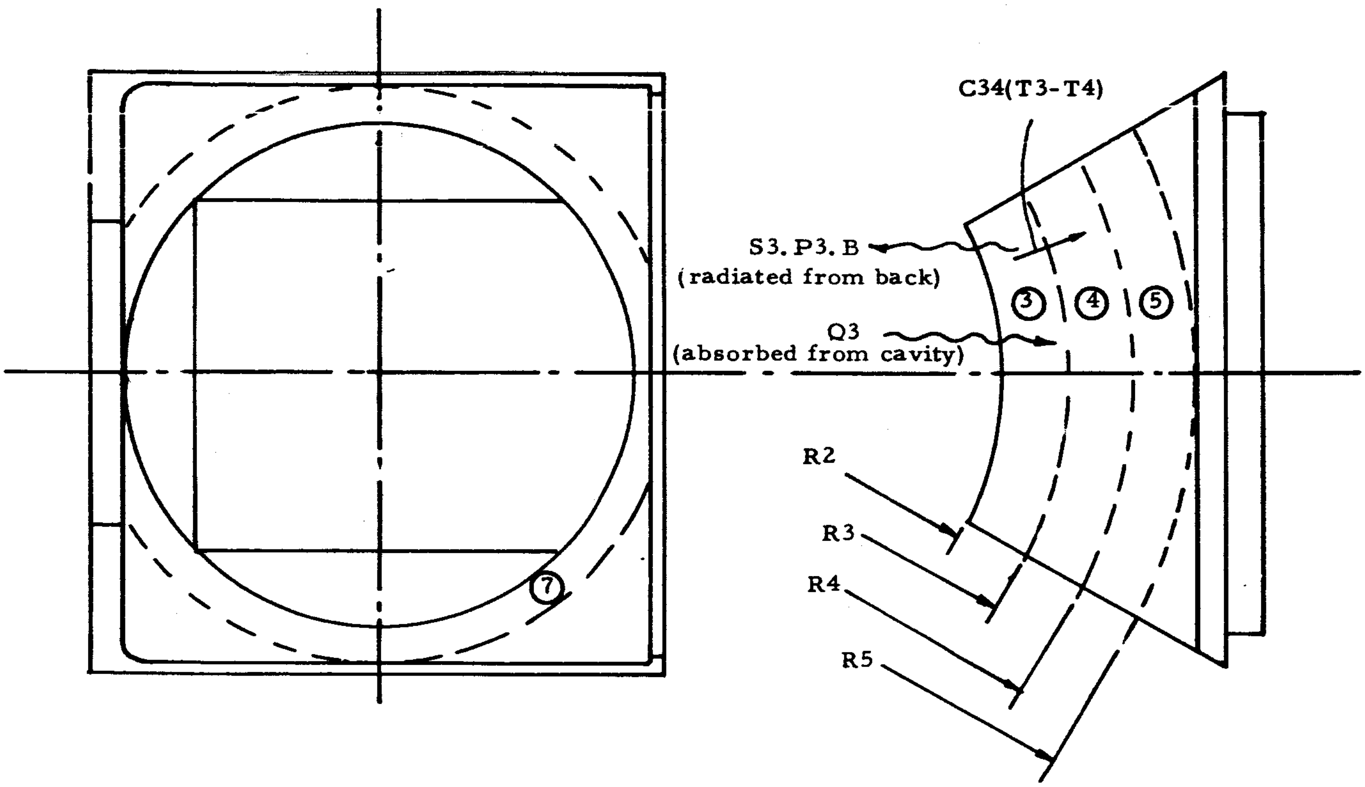


Figure 6. Shoe Piece Heat Transfer Elements and Typical Heat Transfer Terms

where b and Cij are radiation and conduction heat transfer constants which determine the magnitude of individual heat transfer terms for the shoe piece elements. Assuming that the effectiveness of the shielding of the shoe piece elements is equivalent to reducing the radiation losses to 10% of black body, B = 0.10.

The calculation of C34, C45, C57 and C76 is performed as follows:

$$Cij = ks/x \tag{14}$$

where k is the thermal conductivity of tantalum, assumed to be 0.80 watts/ cm-deg C, s is the average cross-sectional area of each element interface:

$$s34 = \pi * R3 * \text{thickness} = .765 \text{ sq. cm.}$$

$$s45 = \pi * R4 * \text{thickness} = .925 \text{ sq. cm.}$$

$$s57 = \pi * R5 * \text{thickness} = 1.080 \text{ sq. cm.}$$

assuming that the shoe piece extension measures .040 in. in thickness, and similarly:

$$x76 = .264 \text{ sq. cm.}$$

assuming that the thickness of the main shoe piece element is .020 in., and x is the average element heat transfer distance:

x34 = .25 cm.

x45 = .25 cm.

x57 = .50 cm. (assumed)

x76 = .50 cm.

The value of x76 is assumed as large as 0.50 cm. to account for the relatively poor thermal contact expected between elements S6 and S7.

Using the above values in Equation 14, the calculation of the conduction constants yields:

C34 = 2.45 watt/deg. C

C45 = 2.96 watt/deg. C

C57 = 1.73 watt/deg. C

C76 = 0.42 watt/deg. C

1.3.6 Computer Program

To solve Equations 2 to 13, it is still needed to establish the temperature of the rear cavity piece T2. Since previous studies have confirmed that it is desirable that this temperature be as high as possible to reduce generator thermal losses, Figure 7 indicates what is the maximum achievable temperature from the standpoint of evaporation rate for tantalum. If a limit of 1.2 mils per year is adopted, the corresponding maximum rear cavity temperature is 2360 deg. K. Although the final design specifies that this piece is made of W, this assumption regarding its upper temperature limit has been maintained.

The computer program required to solve the heat balance problem is presented in flow diagram form in Figure 8, and in actual form in Figure 8a, and it includes an iteration loop to solve the non-linear simultaneous Equations (10) to (13).

1.3.7 Numerical Solutions

The computer program was used to calculate the cavity heat transfer at 3 values of aperture, assuming the performance of JPL concentrator S/N1 as illustrated in Figure 9. The cavity aperture diameters were 0.9, 1.0, and 1.2 inches respectively. As in previous thermionic generator designs, surface emissivities and absorptivities were assumed equal to 0.25 and 0.50 respectively,

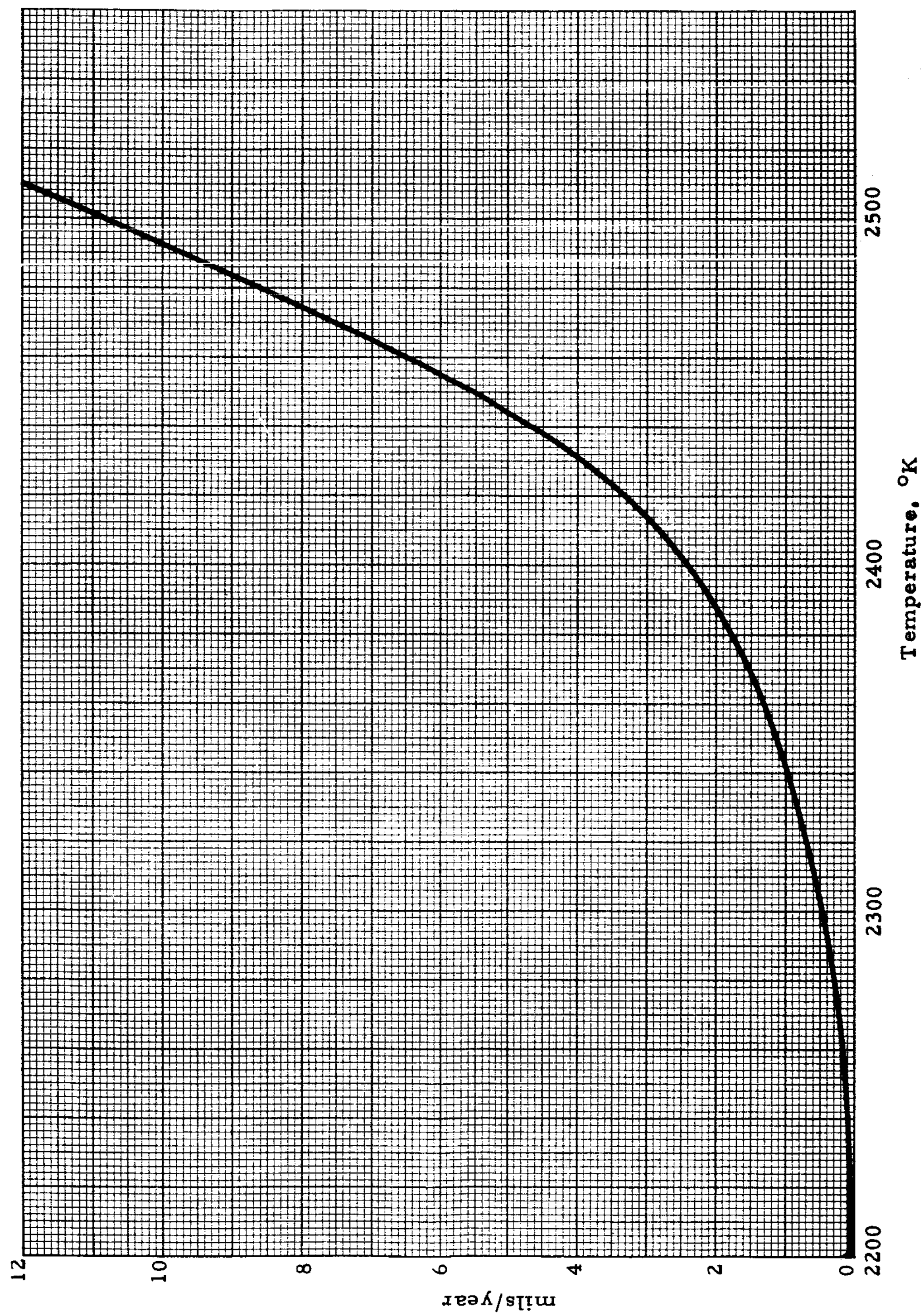


Figure 7. Evaporation Rate of Tantalum

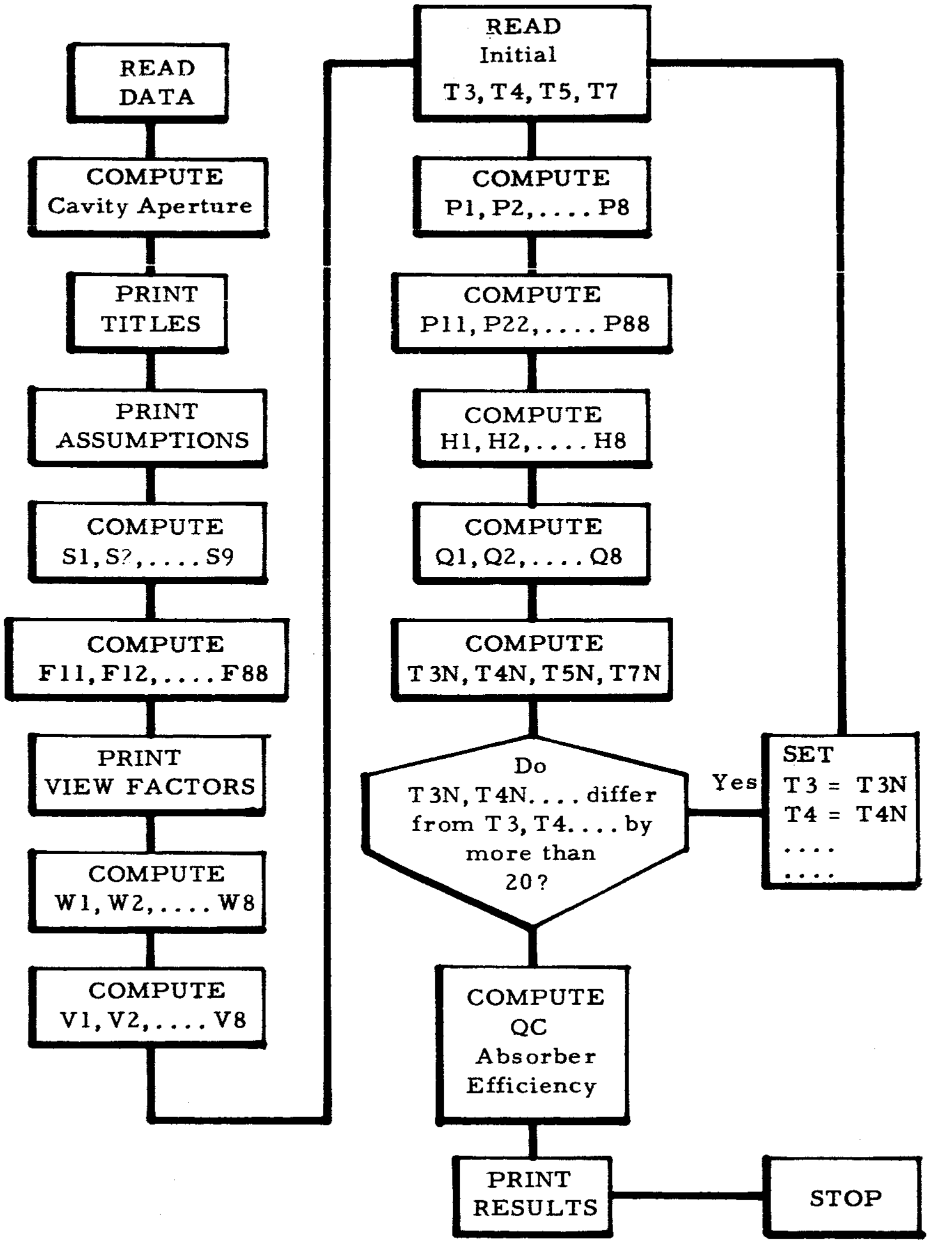


Figure 8. Computer Program Flow Chart

6167

```
      PROGRAM FOR TEECO
      EXTERNAL NEWSOL
      DIMENSION F(8,8),FF(8),E(8),P(8),[illegible],A(8),T(8),[illegible],V(8),[illegible],
     1[illegible](8,8),EPS(8),S(8),[illegible](8),D(4,4),[illegible](4)
    1 READ 2,NA
    2 FORMAT(I5)
      READ 3,(A(I),I=1,NA)
      READ 3,(E(I),I=1,NA)
      READ 3,(FF(I),I=1,NA)
      READ 3,(T(I),I=1,NA)
    4 READ 3,C34,C45,C57,C78,B,WATT,CA
    3 FORMAT(8F10.5)
      READ 5,R1,R2,R3,R4,R5,R6,Z1,Z7,Z8,Z9
    5 FORMAT(10F8.5)
      PRINT 10,CA,WATT
   10 FORMAT(1H1,33X,34HCOMPUTED GENERATOR THERMAL BALANCE//,30X,
     124HCAVITY APERTURE (INCH) =,F6.3,//,30X,27HTOTAL SOLAR INPUT (WATT
     15) =,F8.3,/)
      PRINT 11,R1,R2,R3,R4,R5,R6,Z1,Z7,Z8,Z9
   11 FORMAT(23H CAVITY DIMENSIONS (CM),/,5H R1 =,F5.3,3X,4HR2 =,F5.3,
     13X,4HR3 =,F5.3,3X,4HR4 =,F5.3,3X,4HR5 =,F5.3,/,5H R6 =,F5.3,3X,
     24HZ1 =,F5.3,3X,4HZ7 =,F5.3,3X,4HZ8 =,F5.3,3X,4HZ9 =,F5.3,/)
      PRINT 12,(A(I),I=1,8)
   12 FORMAT(27H CAVITY ABSORPTIVITIES,/,5H A1 =,F4.2,3X,4HA2 =,F4.2,3X,
     14HA3 =,F4.2,3X,4HA4 =,F4.2,/,5H A5 =,F4.2,3X,4HA6 =,F4.2,3X,4HA7 =
     2,F5.2,3X,4HA8 =,F4.2,/)
      PRINT 13,(E(I),I=1,8)
   13 FORMAT(26H CAVITY EMISSIVITIES,/,5H E1 =,F4.2,3X,4HE2 =,F4.2,3X,
     14HE3 =,F4.2,3X,4HE4 =,F4.2,/,5H E5 =,F4.2,3X,4HE6 =,F4.2,3X,
     24HE7 =,F4.2,3X,4HE8 =,F4.2,/)
      PRINT 14,(FF(I),I=1,8)
   14 FORMAT(31H SOLAR FLUX DISTRIBUTION RATIOS,/,5H F1 =,F6.4,3X,4HF2 =
     1,F6.4,3X,4HF3 =,F6.4,3X,4HF4 =,F6.4,/,5H F5 =,F6.4,3X,4HF6 =,F6.4,
     23X,4HF7 =,F6.4,3X,4HF8 =,F6.4,/)
      PRINT 15,C34,C45,C57,C78,B
   15 FORMAT(44H SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K),/,
     1[illegible] C34 =,F6.2,3X,5HC45 =,F6.2,3X,5HC57 =,F4.2,3X,5HC78 =,F4.2,3X,
     2[illegible] =,F4.2,/)
      PRINT 16,(T(I),I=1,8)
   16 FORMAT(21H TEMPERATURES (DEG K),/,5H T2 =,F10.2,3X,4HT6 =,F10.2,3X
[illegible]
```

Figure 8a.. Computer Program

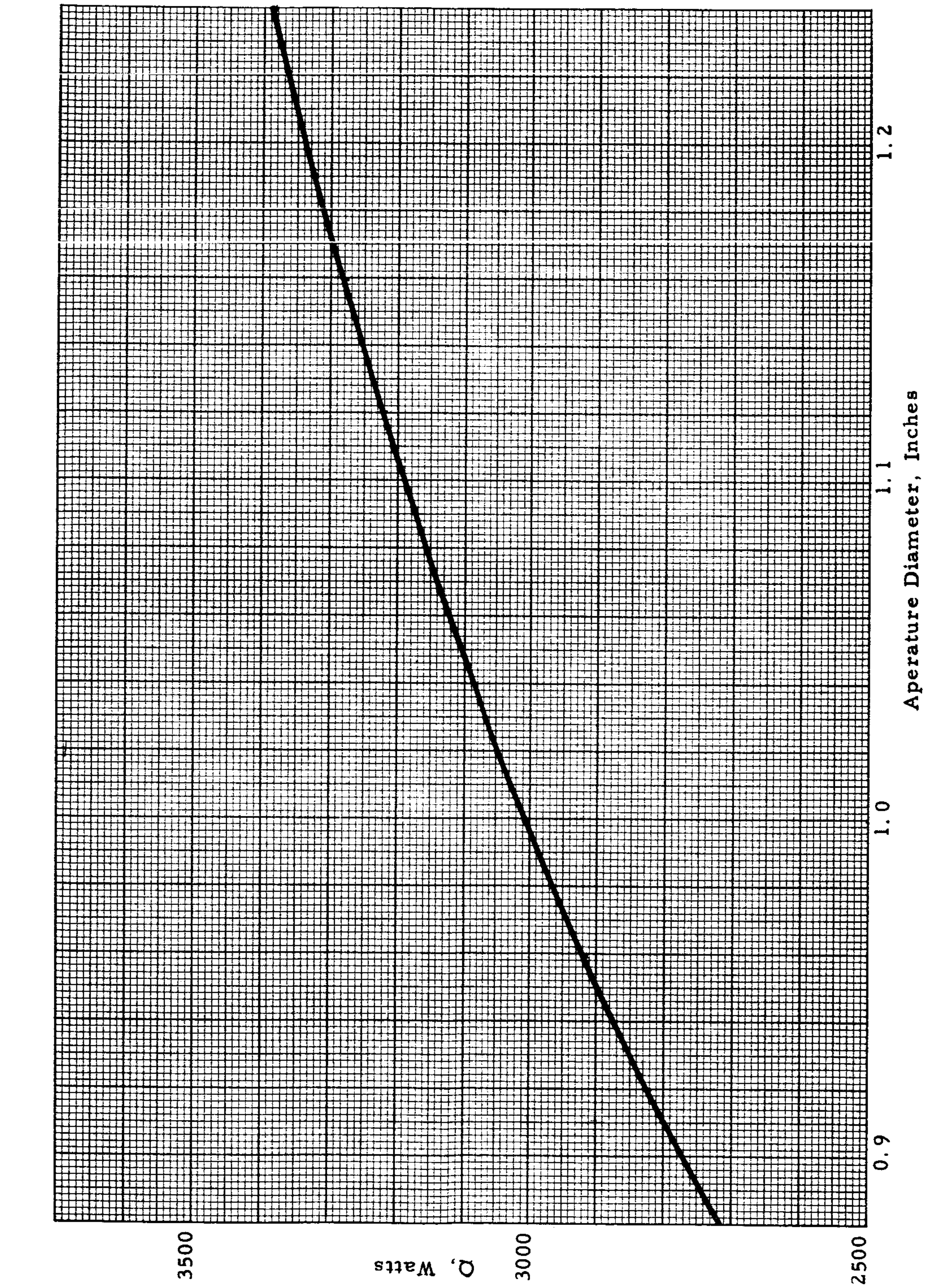


Figure 9. Thermal Power Delivered to the Generator Cavity by JPL Mirror S/N 1

except for the emitter faces where the corresponding values were 0.35 and 0.80. The computer print-outs for these three runs are given in Tables 1, 2 and 3. The corresponding values of heat input QC to the thermionic converters are given in Figure 10. The absorber efficiency QC/w is nearly constant, and it is maximum at an aperture diameter of 0.9 inch. As a result of these calculations, the aperture diameter selected for the generator design is 1.0 inch.

For this value of aperture diameter, the computer was further used to evaluate the generator heat transfer at four different values of heat input, and the corresponding print-outs are given in Tables 4 through 7. The results have been plotted on Figure 11. The four values of heat input would correspond, for JPL concentrator S/N1, to solar fluxes of 50, 70, 90, and 130 watts/ft^2 respectively.

1.4 Generator Thermal Analysis

1.4.1 Converter Heat Losses

The converter heat losses consist of the heat losses which occur in conveying to the emitter the heat QC delivered by the cavity and those which occur after the emitter has received this heat. The first losses occur by radiation from an area illustrated in Figure 12. For a value of e of 0.14 cm. and assuming that the radiation loss to the shielding* is 10 watts per sq. cm. at 2000°K, this loss is:

$$q = \pi \times 1.68 \times 0.14 \times 10 = 7.4 \text{ watts per converter.}$$

The converter losses are calculated assuming the thermal model for the Series VIII converter**:

q (electron cooling) = 2.66 watts/amp.

q (interelectrode radiation) = 28.2 watts

* The Appendix recapitulates the calculation of the ideal radiation heat transfer through a series of N shields.

** Second Monthly Progress Report for Thermal Energy Storage/Converter Prototype Design, Fabrication and Testing, JPL Contract 950976/NAS7-100, April 1965, by S. Merra and L. van Someren, TEE Report TE 77-65.

TABLE 1

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 0.900

TOTAL SOLAR INPUT (WATTS) =2720.000

CAVITY DIMENSIONS (CM)

R1 =1.143 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.134 Z7 =1.730 Z8 =0.705 Z9 =0.404

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.142227+000	0.681801-001	0.719759-001	0.716507-001	0.399243+000	0.161975+000	0.847485-001
0.197483+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.260374+000
0.162692+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.234696+000
0.139826+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.211278+000
0.117377+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.183144+000
0.123203+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.185013+000
0.123203+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.185013+000
0.548547-001	0.121375+000	0.636619-001	0.703940-001	0.723623-001	0.388061+000	0.157439+000	0.718512-001

HEAT RADIATED BY THE CAVITY 516.54714

HEAT ABSORBED BY REAR CAVITY PIECE 34.87

HEAT ABSORBED BY FRONT CONE PIECE 246.00638

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 256.22748

ABSORBER EFFICIENCY (PER CENT) 56.52077

THERMO ELECTRON
ENGINEERING CORPORATION

6163

TABLE 2

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 1.000

TOTAL SOLAR INPUT (WATTS) =3000.000

CAVITY DIMENSIONS (CM)

R1 =1.270 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.045 Z7 =1.730 Z8 =0.550 Z9 =0.315

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.144700+000	0.698512-001	0.739335-001	0.736551-001	0.408169+000	0.165597+000	0.640952-001
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.628636-001	0.120044+000	0.637927-001	0.710671-001	0.734976-001	0.393143+000	0.159501+000	0.560913-001

HEAT RADIATED BY THE CAVITY 657.64063

HEAT ABSORBED BY REAR CAVITY PIECE 42.39

HEAT ABSORBED BY FRONT CONE PIECE 208.71534

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 280.36993

ABSORBER EFFICIENCY (PER CENT) 56.07397

TABLE 3

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APFRTURE (INCH) = 1.200

TOTAL SOLAR INPUT (WATTS) =3328.000

CAVITY DIMENSIONS (CM)

R1 =1.524	R2 =0.970	R3 =1.220	R4 =1.470	R5 =1.720
R6 =0.840	Z1 =1.730	Z7 =1.730	Z8 =0.239	Z9 =0.134

CAVITY ABSORPTIVITIES

A1 =1.00	A2 =0.50	A3 =0.50	A4 =0.50
A5 =0.50	A6 =0.80	A7 = 0.50	A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00	E2 =0.25	E3 =0.25	E4 =0.25
E5 =0.25	E6 =0.35	E7 =0.25	E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000	F2 =0.0591	F3 =0.0645	F4 =0.0732
F5 =0.0770	F6 =0.5162	F7 =0.2100	F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.159880+000	0.782320-001	0.829389-001	0.821420-001	0.406629+000	0.164972+000	0.252065-001
0.394657+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.631997-001
0.331872+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.655166-001
0.286441+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.646622-001
0.239224+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.612967-001
0.223079+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.851363-001
0.223079+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.851363-001
0.755098-001	0.766973-001	0.462654-001	0.560872-001	0.630506-001	0.464885+000	0.188807+000	0.288974-001

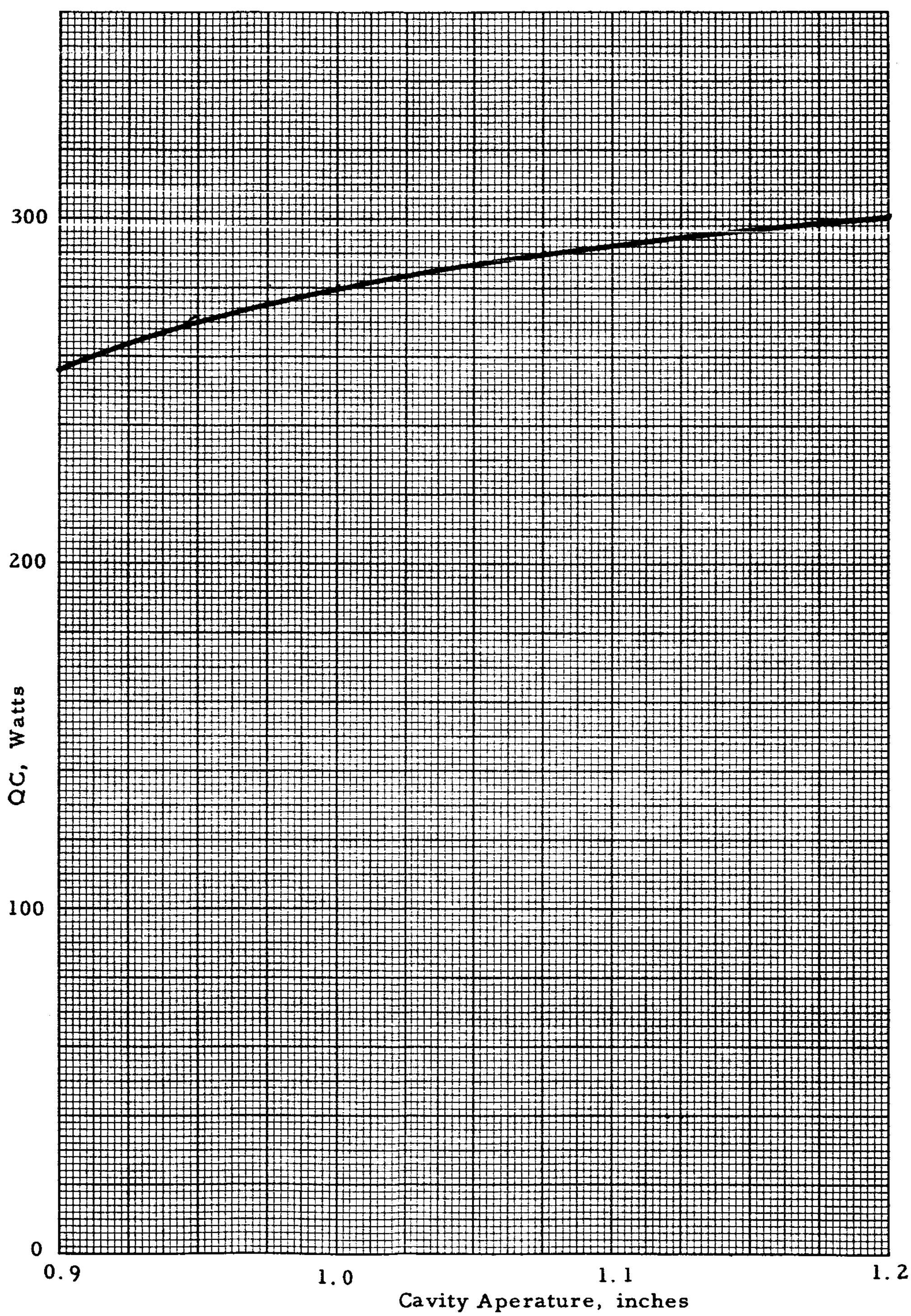
HEAT RADIATED BY THE CAVITY 954.39355

HEAT ABSORBED BY REAR CAVITY PIECE 41.96

HEAT ABSORBED BY FRONT CONE PIECE 98.15934

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 301.17029

ABSORBER EFFICIENCY (PER CENT) 54.29752



Figu e 10. Calculated Converter Thermal Input vs. Cavity Aperature Size

TABLE 4

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 1.000

TOTAL SOLAR INPUT (WATTS) =1666.667

CAVITY DIMENSIONS (CM)

R1 =1.270 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.045 Z7 =1.730 Z8 =0.550 Z9 =0.315

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.144700+000	0.698512-001	0.739335-001	0.736551-001	0.408169+000	0.165597+000	0.640952-001
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.628636-001	0.120044+000	0.637927-001	0.710671-001	0.734976-001	0.393143+000	0.159501+000	0.560913-001

HEAT RADIATED BY THE CAVITY 493.09972

HEAT ABSORBED BY REAR CAVITY PIECE -21.37

HEAT ABSORBED BY FRONT CONE PIECE 143.06495

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 134.04160

ABSORBER EFFICIENCY (PER CENT) 48.25496

TABLE 5

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 1.000

TOTAL SOLAR INPUT (WATTS) =2333.333

CAVITY DIMENSIONS (CM)

R1 =1.270 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.045 Z7 =1.730 Z8 =0.550 Z9 =0.315

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.144700+000	0.698512-001	0.739335-001	0.736551-001	0.408169+000	0.165597+000	0.640952-001
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.628636-001	0.120044+000	0.637927-001	0.710671-001	0.734976-001	0.393143+000	0.159501+000	0.560913-001

HEAT RADIATED BY THE CAVITY 570.72771

HEAT ABSORBED BY REAR CAVITY PIECE 10.17

HEAT ABSORBED BY FRONT CONE PIECE 174.77482

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 207.25403

ABSORBER EFFICIENCY (PER CENT) 53.29391

TABLE 6

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 1.000

TOTAL SOLAR INPUT (WATTS) =3000.000

CAVITY DIMENSIONS (CM)

R1 =1.270 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.045 Z7 =1.730 Z8 =0.550 Z9 =0.315

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.144700+000	0.698512-001	0.739335-001	0.736551-001	0.408169+000	0.165597+000	0.640952-001
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.628636-001	0.120044+000	0.637927-001	0.710671-001	0.734976-001	0.393143+000	0.159501+000	0.560913-001

HEAT RADIATED BY THE CAVITY 657.64063

HEAT ABSORBED BY REAR CAVITY PIECE 42.39

HEAT ABSORBED BY FRONT CONE PIECE 208.71534

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 280.36993

ABSORBER EFFICIENCY (PER CENT) 56.07397

TABLE 7

COMPUTED GENERATOR THERMAL BALANCE

CAVITY APERTURE (INCH) = 1.000

TOTAL SOLAR INPUT (WATTS) =4333.333

CAVITY DIMENSIONS (CM)

R1 =1.270 R2 =0.970 R3 =1.220 R4 =1.470 R5 =1.720
R6 =0.840 Z1 =2.045 Z7 =1.730 Z8 =0.550 Z9 =0.315

CAVITY ABSORPTIVITIES

A1 =1.00 A2 =0.50 A3 =0.50 A4 =0.50
A5 =0.50 A6 =0.80 A7 = 0.50 A8 =0.50

CAVITY EMISSIVITIES

E1 =1.00 E2 =0.25 E3 =0.25 E4 =0.25
E5 =0.25 E6 =0.35 E7 =0.25 E8 =0.25

SOLAR FLUX DISTRIBUTION RATIOS

F1 =0.0000 F2 =0.0591 F3 =0.0645 F4 =0.0732
F5 =0.0770 F6 =0.5162 F7 =0.2100 F8 =0.0000

SHOE PIECE HEAT TRANSFER FACTORS (WATT/DEG K)

C34 =2.45 C45 =2.95 C57 =1.73 C76 =0.42 B =0.20

TEMPERATURES (DEG K)

T2 = 2360.00 T6 = 2000.00 T8 = 1000.00

VIEW FACTORS

0.000000+000	0.144700+000	0.698512-001	0.739335-001	0.736551-001	0.408169+000	0.165597+000	0.640952-001
0.248046+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.385673+000	0.156470+000	0.209811+000
0.205777+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.428690+000	0.173922+000	0.191611+000
0.177320+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.461616+000	0.187281+000	0.173784+000
0.148963+000	0.000000+000	0.000000+000	0.000000+000	0.000000+000	0.497600+000	0.201880+000	0.151557+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.155502+000	0.857142-001	0.554392-001	0.733268-001	0.937349-001	0.272866+000	0.110704+000	0.152713+000
0.628636-001	0.120044+000	0.637927-001	0.710671-001	0.734976-001	0.393143+000	0.159501+000	0.560913-001

HEAT RADIATED BY THE CAVITY 833.64928

HEAT ABSORBED BY REAR CAVITY PIECE 107.04

HEAT ABSORBED BY FRONT CONE PIECE 277.12372

NET HEAT RECEIVED BY EMITTER PIECE OF EACH CONVERTER 424.91321

ABSORBER EFFICIENCY (PER CENT) 58.83415

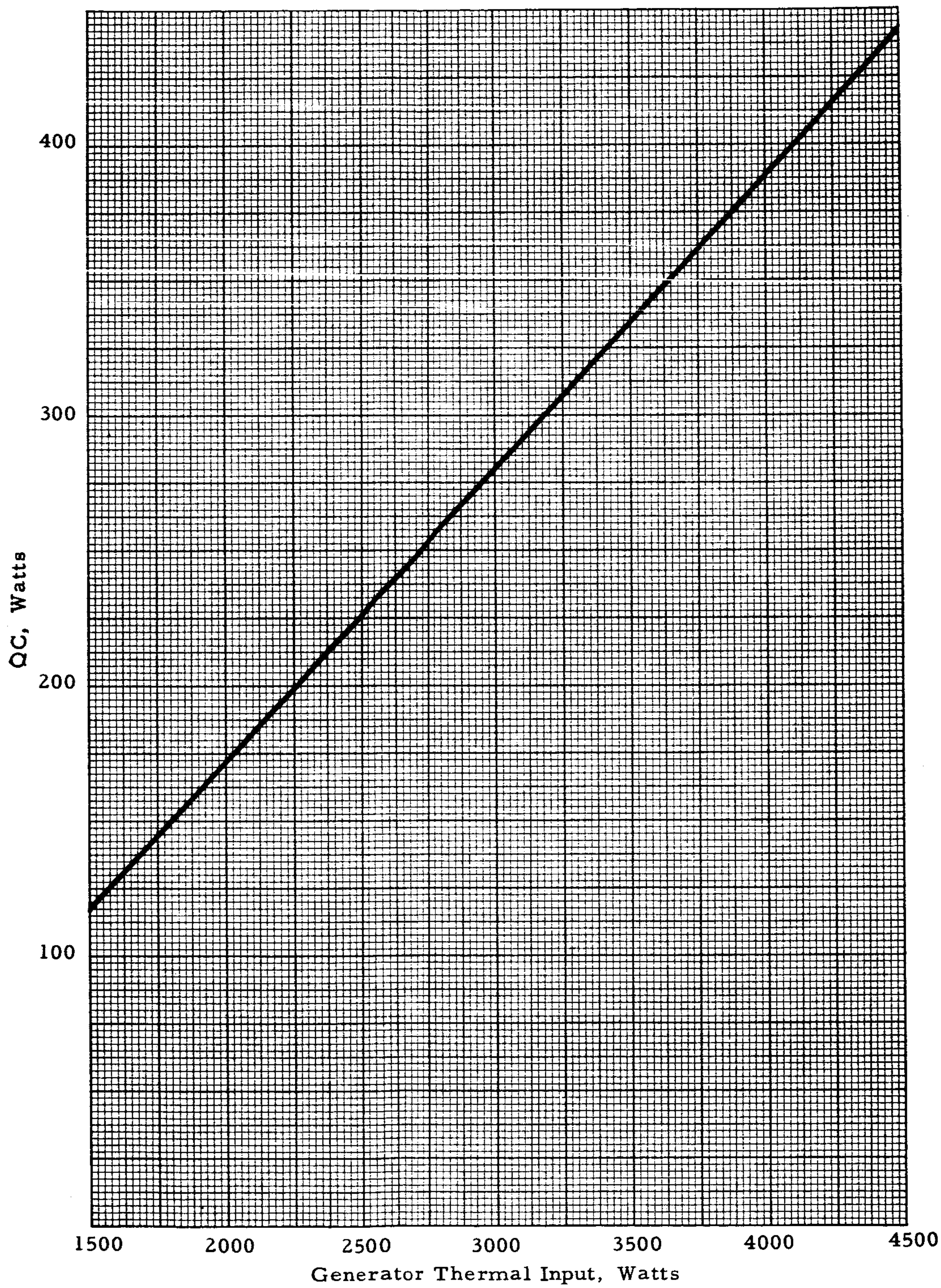


Figure 11. Calculated Thermal Input at Converter vs. Generator Thermal Input

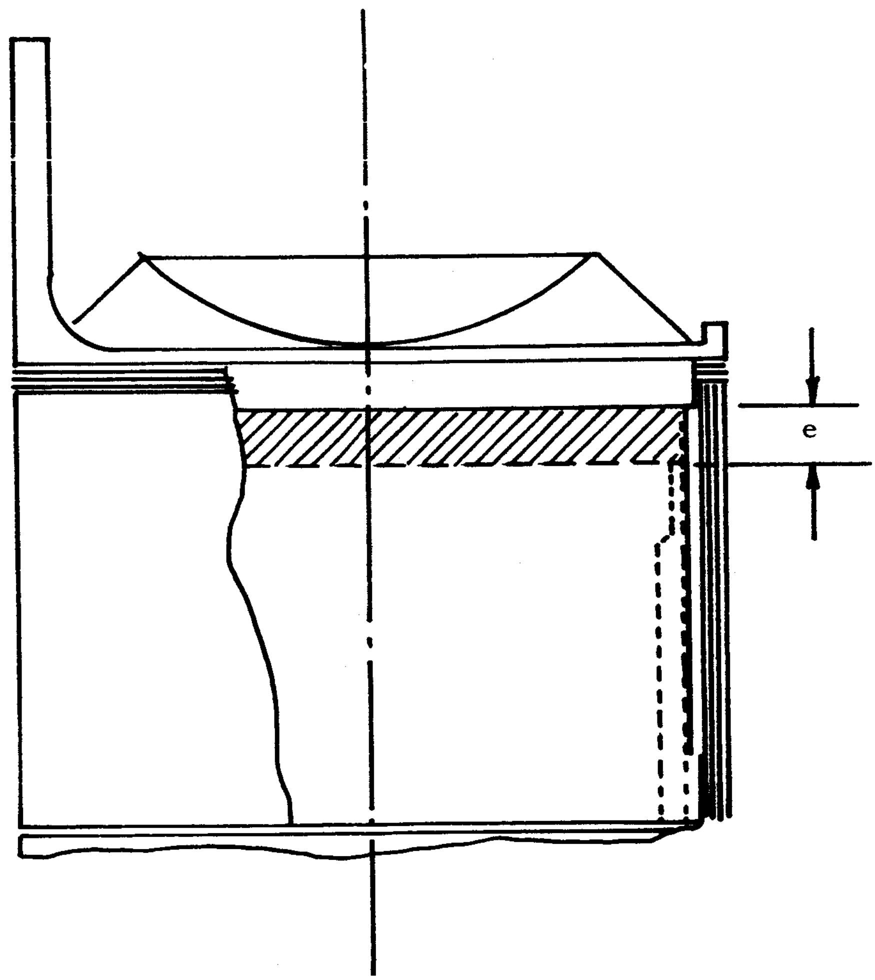


Figure 12. Converter Heat Loss Area

q(cesium conduction) = 10.0 watts

q(emitter support) = 39.0 watts

The total converter losses at 2000°K are then given in terms of the output current by:

$$QC = 77.2 + 7.4 + 2.66\, I_o \text{ watts}$$

and this relationship is plotted in Figure 13.

For the four calculated values of QC of 134, 207, 280, and 425 watts, the corresponding values of converter output current are 18.5, 46.2, 73.5, and 128 amperes respectively.

1.4.2 Rear Cavity Heat Losses

The rear cavity piece rejects the heat received from the cavity by radiation and by conduction. The radiator occurs from the back side and from the lateral area and it is computed as follows:

Average diameter of support sleeve:	1.4 cm
Length of support sleeve:	0.8 cm
Tantalum conductivity:	0.7 watts/cm-deg C
Heat loss at back side:	$q_B = \epsilon A \sigma T^4$ $T = 2360$ deg K
	$= 0.25 \times 1.54 \times 176.2$
	$=$ 68 watts for unshielded case
	$= 0.25 \times 68 = 17$ watts for shielded case
Lateral radiation:	$q_L = \epsilon \pi D L' \sigma T^4$ $L' = 0.4$ cm assumed
	$= 0.440 \times 176.2 = 78$ watts
Conduction heat transfer:	$q_C = kA(T_1 - T_2)/L$ $T_2 = 1200$ deg K assumed

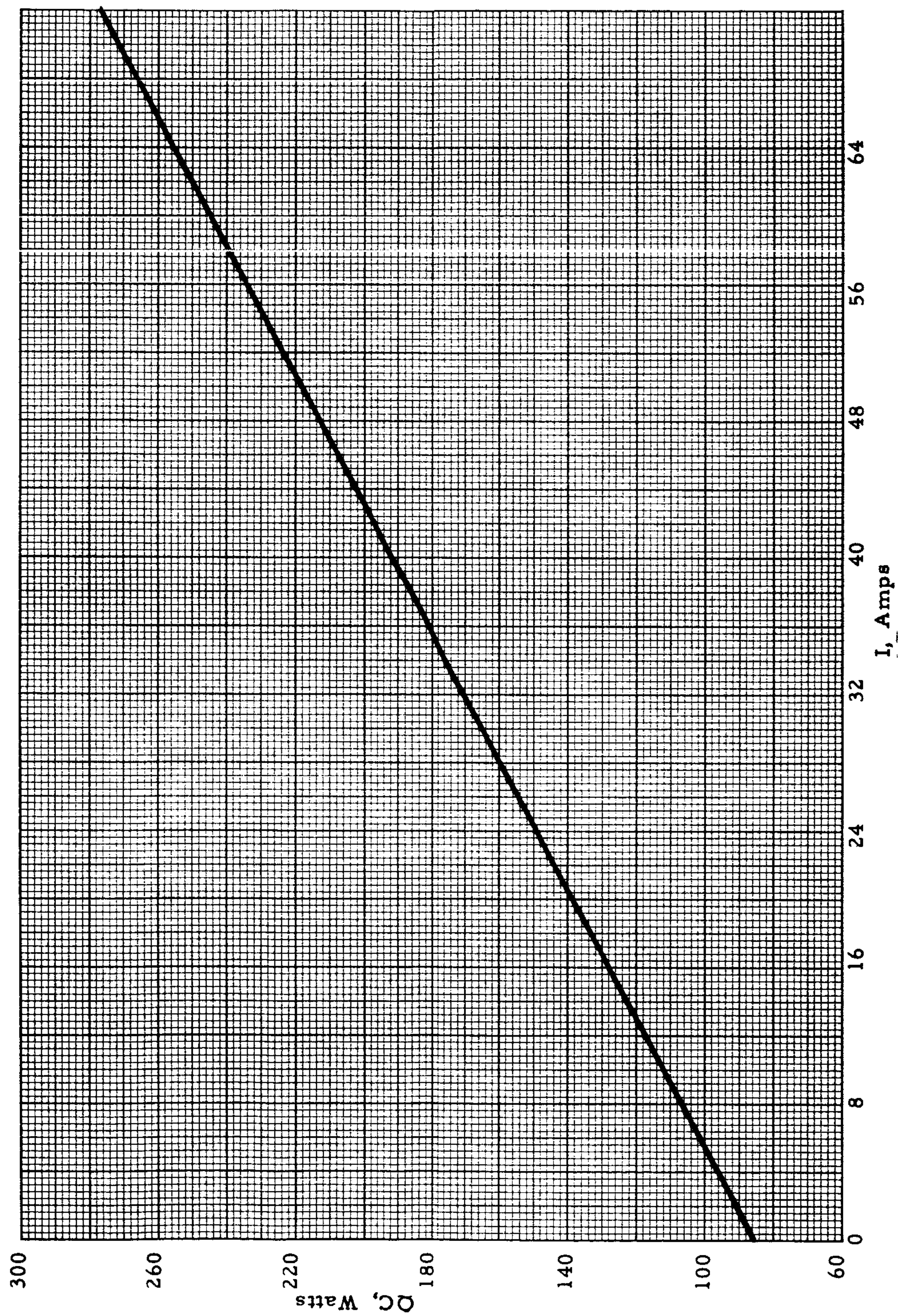


Figure 13. Converter Output Current vs. Thermal Input at $2000^{o}K$

$$q_C = 0.7 \times \pi \times 1.4 \times t \times 1160/.8$$

$$= 4460\ t \text{ watts for } t \text{ expressed in cm}$$

$$= 11.15\ t \text{ watts for } t \text{ expressed in mils}$$

Total loss: $q_{shielded} = 95 + 11.15\ t$ watts

$q_{unshielded} = 146 + 11.15\ t$ watts

These relationships are plotted in Figure 14. It is seen that for the maximum input predicted of 107 watts, the cavity piece should have a support sleeve thickness of 1 mil and that shielding is required. Since a thickness of 1 mil is not realistic for an element of this size, the selection of the thickness of the supporting sleeve must be governed by structural considerations. A thickness of 5 mils would be practical.

1.4.3 Generator Radiator Heat Transfer

The lateral area of the generator radiator can be calculated by assimilating the geometry to a cylinder with a height of 4.5 cm and a diameter of 6.7 cm. Its value is 95.7 cm^2. The area at the bottom of this radiator corresponds to that of a circle with a diameter of 9.77 cm or 74.7 cm^2. The total area of the generator radiator is thus 170.4 cm^2. At an effective emissivity of 0.85, the heat radiated as a function of temperature is given by Figure 15. If it is conservatively assumed that the heat received by the radiator is equal to 80% of the heat absorbed by the rear cavity piece, Q2, and the emitter shoe pieces, (Q3 + Q4 + Q5 + Q7), the maximum heat rejection at 90*w/sq. ft. for the generator radiator is 435 watts, and the corresponding average radiator temperature will be 852 deg K, which is an acceptable value in terms of conventional generator design practice.

* The case at 130 w/sq. ft. is not considered because it results in an obvious overheated condition for the generator, viz., 128 amperes per converter when the maximum design current of Series VIII converters is of the order of 75 amps.

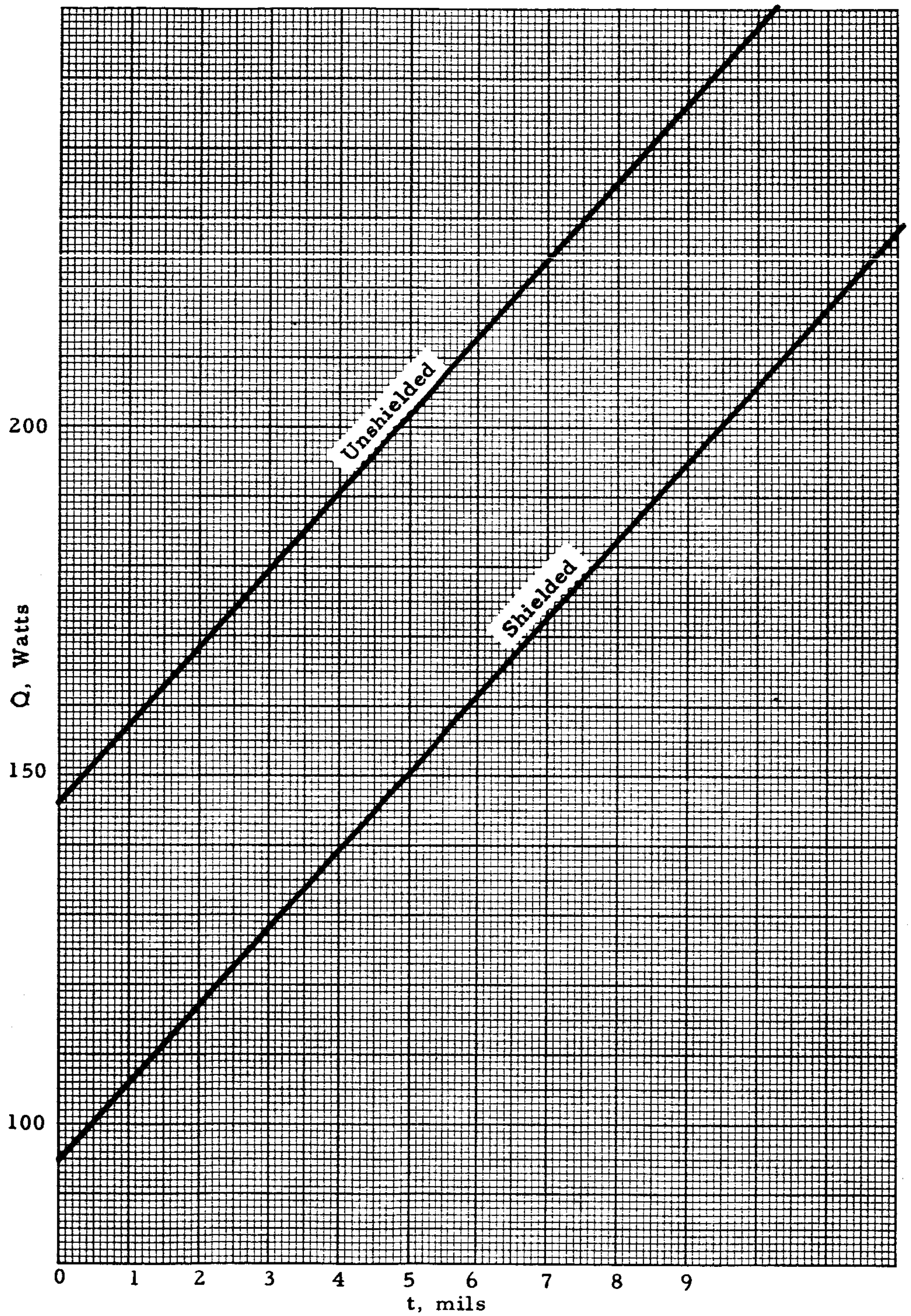


Figure 14. Heat Transfer Characteristics of Rear Cavity Piece

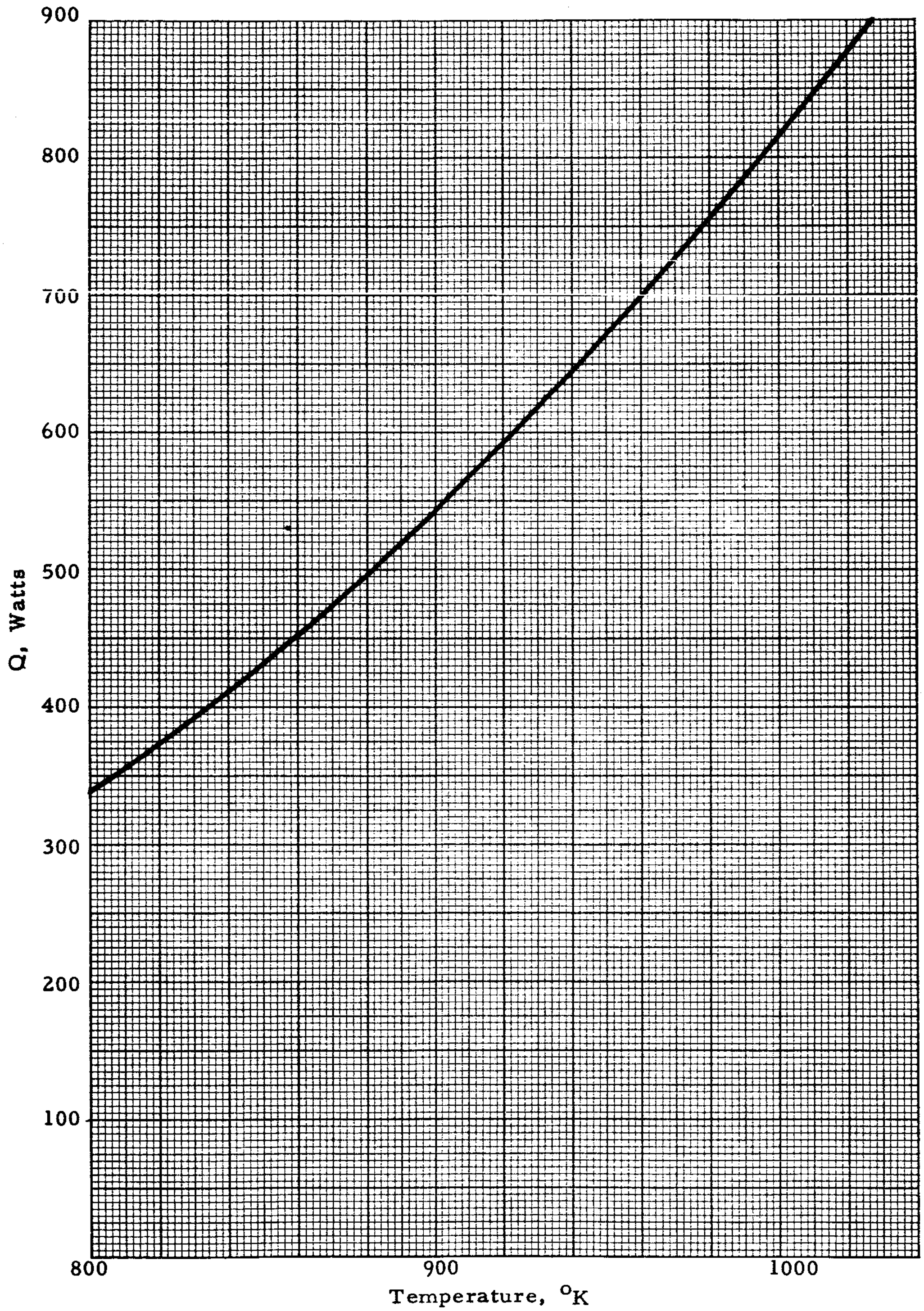


Figure 15. Heat Transfer Characterisitc for Generator Radiator

1.5 Generator Electrical Output Characteristics

1.5.1 Generator I-V Characteristic

The generator I-V characteristic is simply obtained by multiplying by 6 the output voltage of an individual converter and subtracting from it the expected voltage drop in the interconnecting leads. Figure 16 shows a representative I-V characteristic for a Series VIII converter obtained on converter VIII-S-9 (May 14, 1965). The voltage drop in interconnecting leads was measured on converter VIII-P-3 (August 12, 1964 Data Sheet 27), and it amounted to 1.45 millivolt/ampere for a single converter, or 8.70 millivolts/ampere in a series of 6 converters. This loss is plotted in Figure 17. Figure 18 then gives the expected generator I-V characteristic.

1.5.2 Generator Output

For the four selected values of heat input, the corresponding output currents were found in Section 1.4.1 to be 18.5, 46.2, 73.5, and 128 amperes respectively. Figure 18 shows that at the three lower output currents, the output voltages will be 5.2, 4.0 and (by extrapolation) 2.35 volts. Figure 19 gives the resulting curves of generator power output, generator-absorber efficiency, P_G/W, and generator efficiency, $P_G/(W - QBB)$, where QBB is the radiation loss from a black body cavity at $2000^{\circ}K$ and having an aperture of 1.0 inch (460 watts). As may be seen, the design goal of an efficiency of 10% for a maximum power input of 2500 watts is not achieved. This is because of insufficient electrical output from the converters at any value of heat input. The maximum power output of a Series VIII converter at $2000^{\circ}K$ is found from Figure 16 to be at 0.55 volts, and is equal to 37.4 watts. It is thus seen that for 6 converters, without considering the voltage drop in the interconnecting leads, the maximum possible power output is only 225 watts.

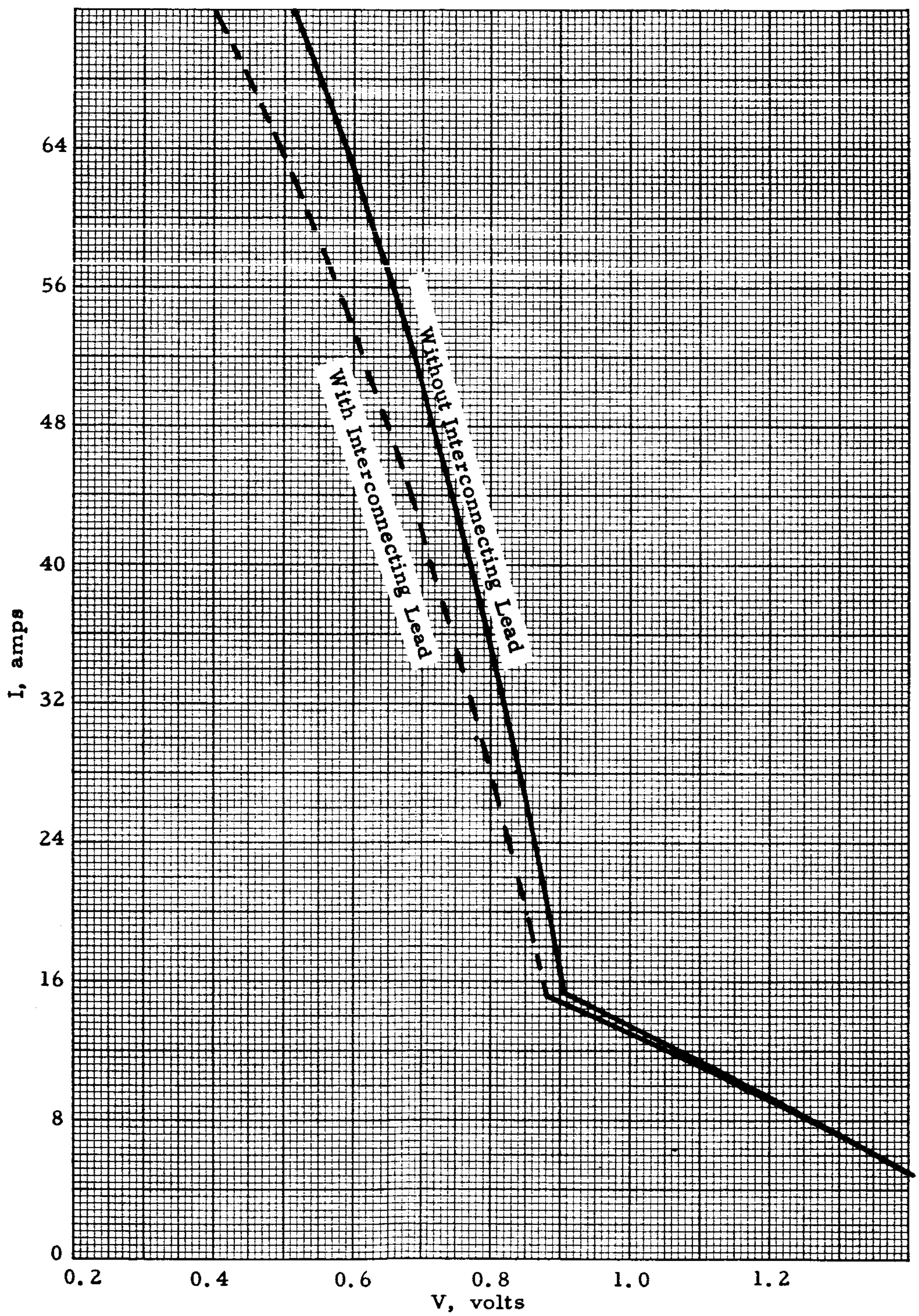


Figure 16. Converter I-V Characteristic

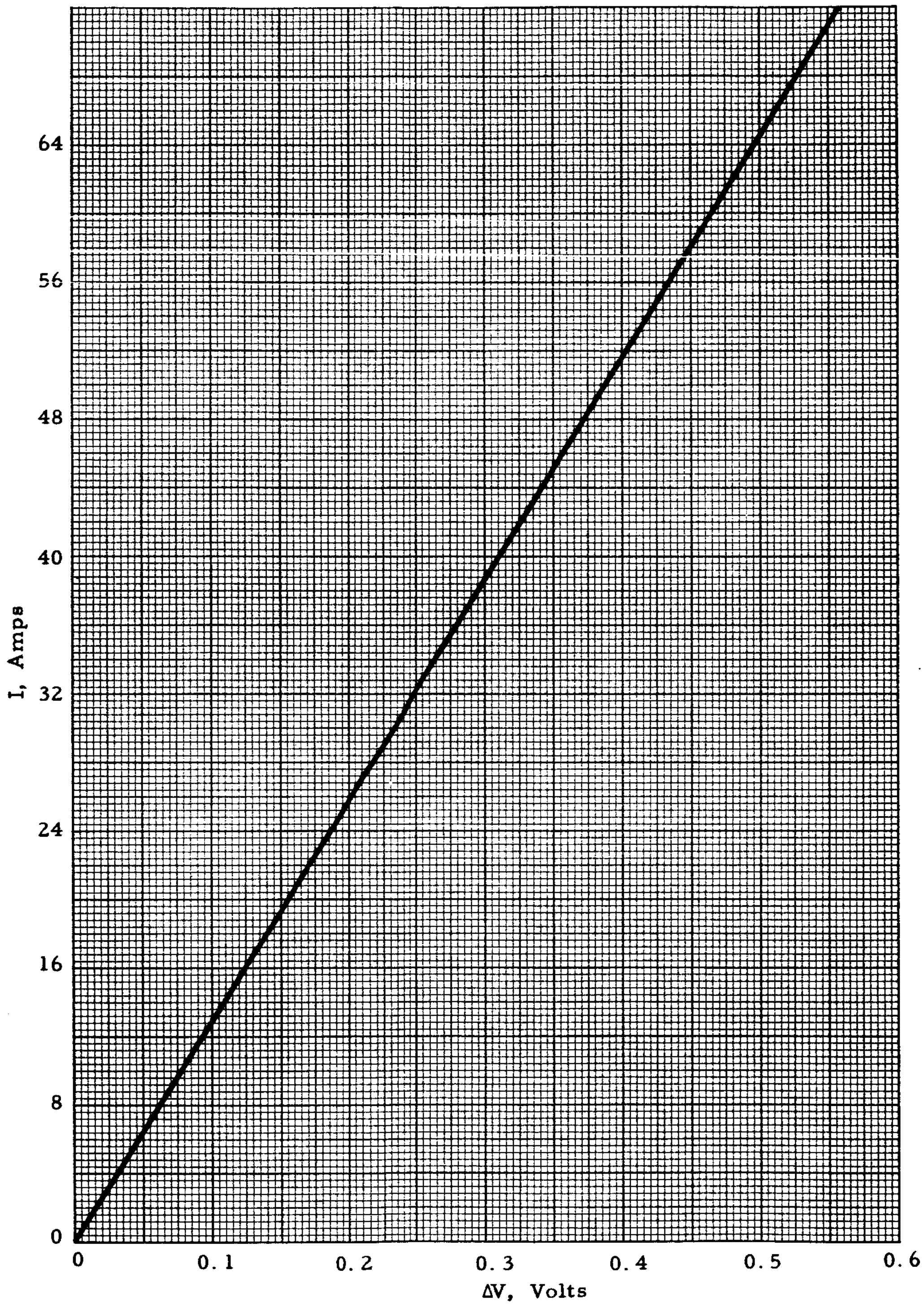


Figure 17. Voltage Drop in Interconnecting Leads

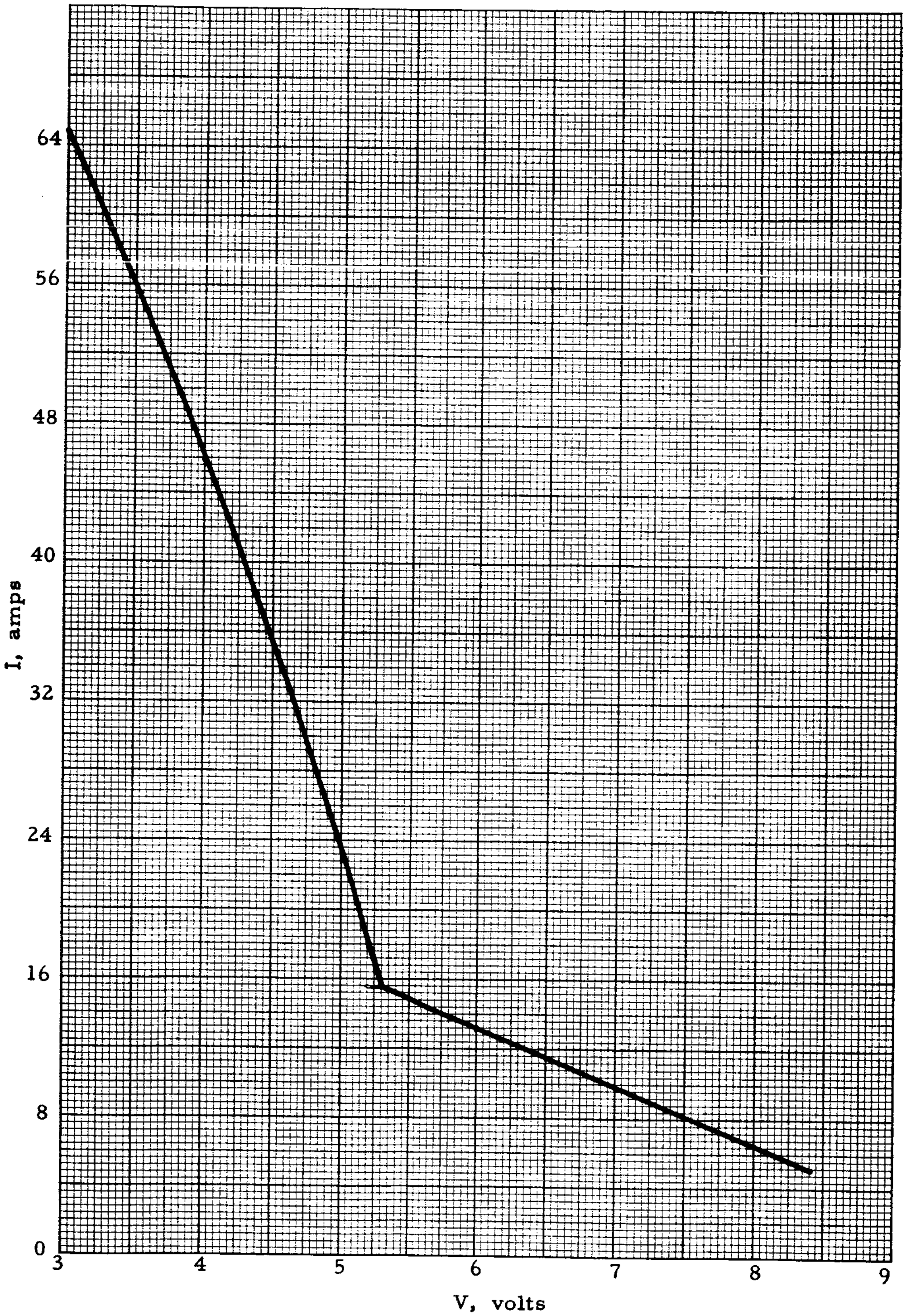


Figure 18. Generator I-V Characteristic

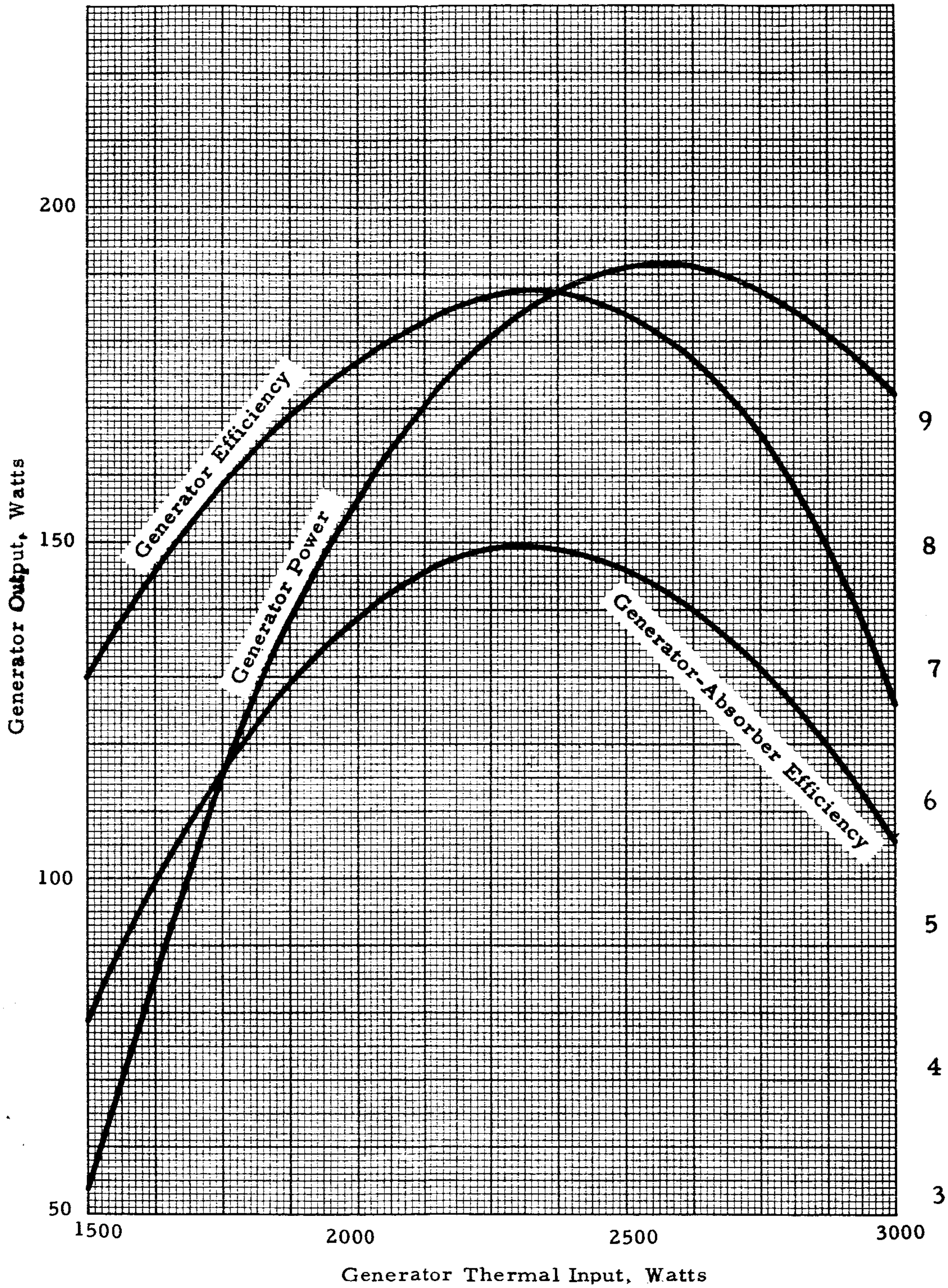


Figure 19. Generator Output Efficiency vs. Thermal Input

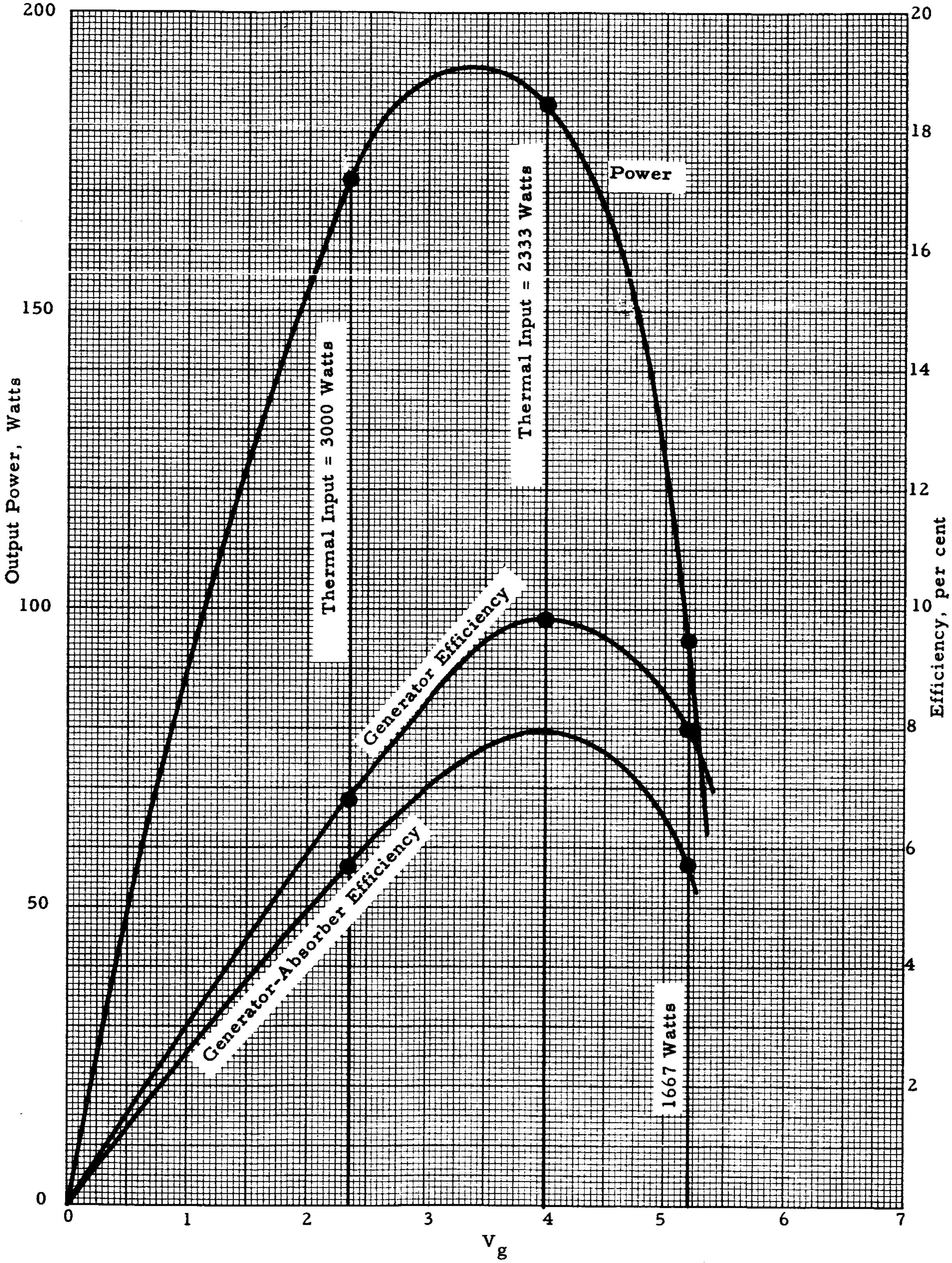


Figure 19a. Generator Output and Efficiency vs. Output Voltage

1.6 Calculation of Changes of Critical Clearances

1.6.1 Adjacent Emitter Shoe Pieces

Figure 20 shows the geometry of the clearance between adjacent emitter shoe pieces. For longitudinal and transverse displacements ℓ and r respectively, due to thermal expansion, the clearance between adjacent emitter shoe pieces changes by:

$$\varepsilon = 1.732\, r + \ell$$

The magnitude of r is given by:

$$r = (\alpha\ \Delta\ T) L_r$$

For tantalum, $(\alpha\ \Delta\ T)$ = 12.9 mils/inch* at 1700°C, the length L_r, is maximum at the plane of the emitter and is equal to 0.38 inch. Therefore, r = 4.90 mils.

The magnitude of ℓ is given by the net difference in expansion between the generator block and the converter emitter structure. The generator block expands by $\ell_b = (\alpha\ \Delta\ T) L_b$.

For molybdenum at 700°C, $(\alpha\ \Delta\ T)$ = 3.8 mils/inch. The length L_b is equal to the distance from the generator axis to the converter support plane and is 1.21 inch.

The emitter structure expands by $\ell_e = (\alpha\ \Delta\ T) L_e$ where L_e = 0.47 inch and $(\alpha\ \Delta\ T)$ is the thermal expansion of tantalum at the average temperature (1700 + 700)/2 = 1200°C which is 8.6 mils/inch.

We then find:

$$\ell = 0.47 \times 8.6 - 1.21 \times 3.8 = -.56 \text{ mils}$$

and,

$$\varepsilon = 1.732 \times 4.90 - .56 = \underline{7.9 \text{ mils}}$$

is the decrease in the clearance between adjacent emitter shoe pieces. If the spacing between these elements at room temperature is 20 mils, at operating

* Handbook of Thermophysical Properties of Materials.

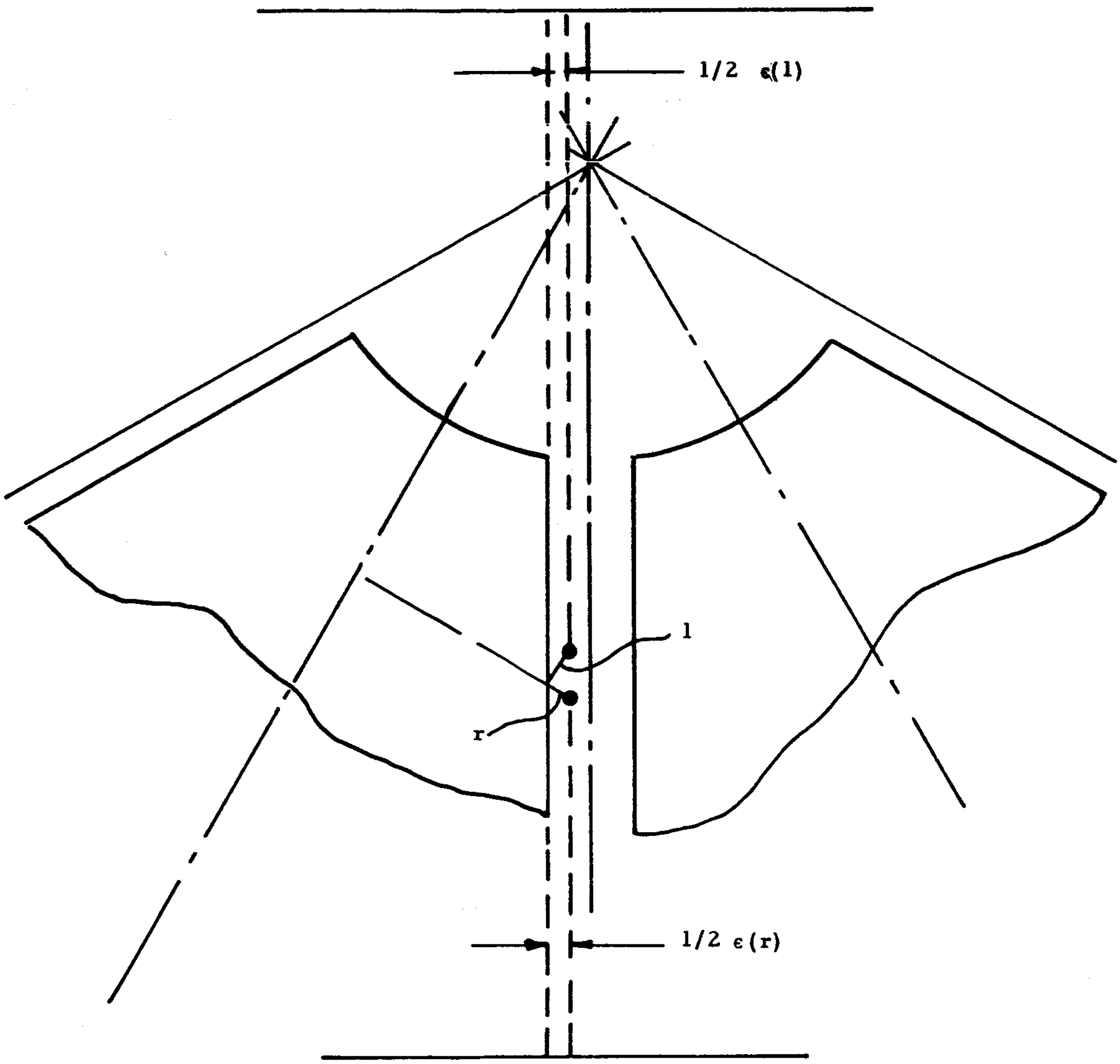


Figure 20. Critical Clearance Dimensions

temperature it will be 12 mils, a value which is consistent with thermionic generator design practice, particularly for one with a somewhat more complicated geometry.

1.6.2 Shoe Piece - Rear Cavity Piece

The change in this clearance is given by the sum of the radial expansion of the rear cavity piece and the value of ℓ corresponding to the tip of a shoe piece.

The radial expansion of the rear cavity piece is given by:

$$r_r = R\ (\alpha \Delta T)$$

For the temperature achieved by the rear cavity piece of 2360°K or 2087°C, $(\alpha \Delta T)$ equals 10.8 mils/inch. Since the rear cavity piece has a radius of 0.38 inch, $r_r = 4.1$ mils.

The value of ℓ corresponding to the tip of a shoe piece is obtained by adding a term $L(\alpha \Delta T)$ to the previous calculated value of ℓ:

$$L = 0.3 \text{ inch}$$

$$(\alpha \Delta T), \text{ tantalum at } 1700°C = 12.9 \text{ mils/inch}$$

$$\ell_{tip} = -.56 + 3.87 = 3.31 \text{ mils}$$

The decrease in clearance between the rear cavity piece and the tip of the surrounding shoe pieces is then 4.1 + 3.3 = 7.4 mils. For an initial value of 20 mils, the spacing will thus decrease to 12.6 mils.

1.6.3 Shoe Piece - Front Cone

The change in the clearance between the emitter shoe pieces and the front cone is given by the difference between the radial emitter expansion, which has already been calculated as being 4.90 mils, and the displacement of the front cone. This last term is again a term $L(\alpha \Delta T)$ where L is the distance from the center line of a converter to the plane of the front cone or 0.39 inch,

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and $(\alpha \Delta T)$ is the thermal expansion of molybdenum at 700° C: 3.8 mils/inch. The displacement of the front cone is then: 2.8 x 0.39 = 1.48 mils.

The decrease in clearance between the front cone and the emitter shoe pieces is accordingly: 4.90 = 1.48 = 3.4 mils. For an initial value of 20 mils, the spacing will decrease to 16.6 mils.

1.7 Preliminary Design of Electron Bombardment Unit

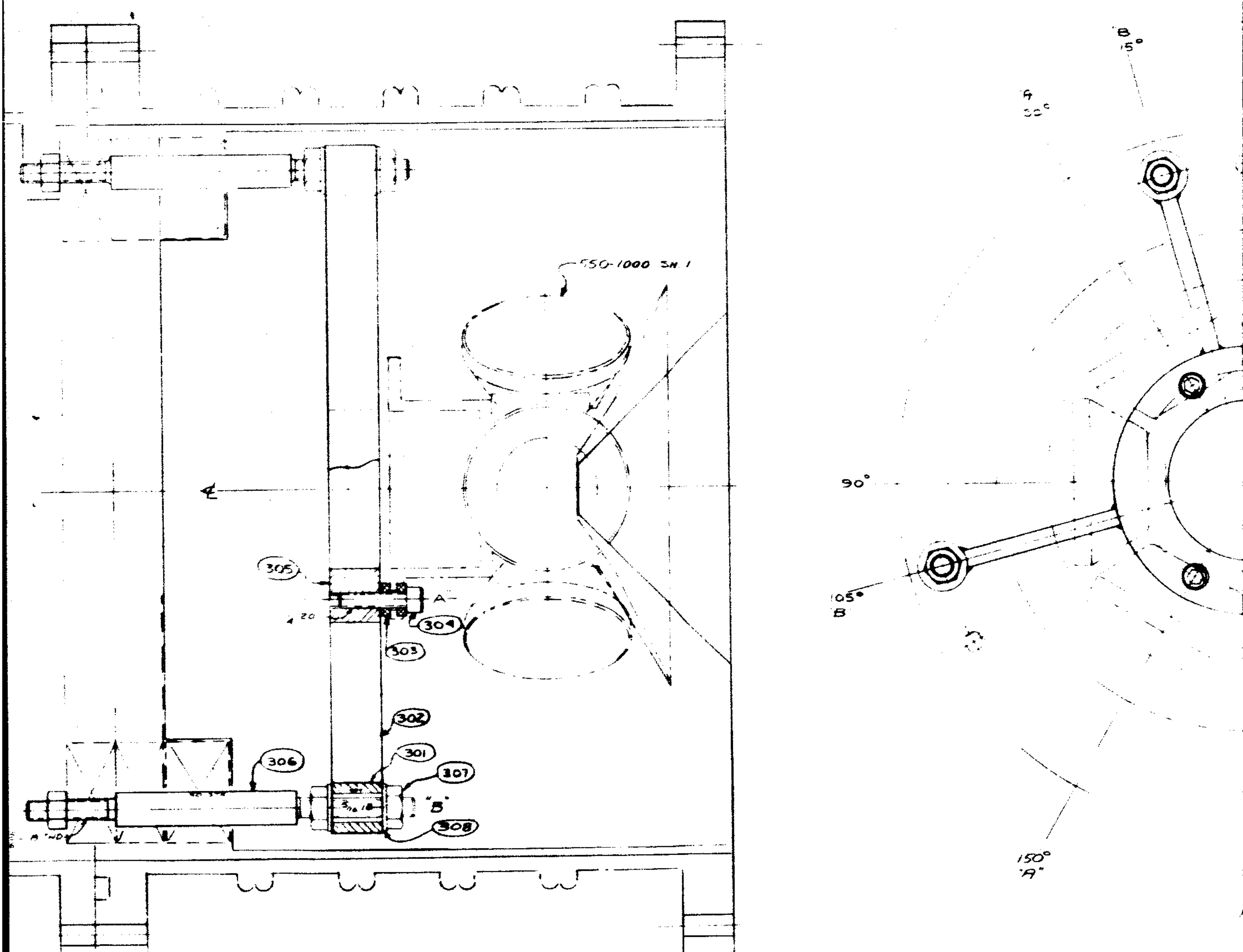
1.7.1 Preliminary Layout

Figure 21, Dwg. 549-1000, shows the initially proposed design for the electron bombardment unit. The unit consists essentially of a concentric filament support structure which holds 6 individual U-shaped filaments. The central support penetrates the cavity to act as an electrostatic shield for the rear cavity piece. Because of its exposure to the cavity thermal radiation, it is important to provide it with a heat barrier section which can reduce the cavity heat losses, without causing overheating of the filament support to such an extent that it becomes an important source of bombardment current. The choice of filament size and the design of the heat barrier section of the control filament support are discussed in the next two sections. The other design features presented by the electron bombardment unit of Figure 21 are:

1. Shielding of the high voltage insulator to prevent metallic deposits and consequent leakage currents.
2. Easy adjustments in traverse and height are provided by two independent sets of 4 screw adjustments.
3. The unit is easily demountable from the generator by releasing 4 thumb screws.

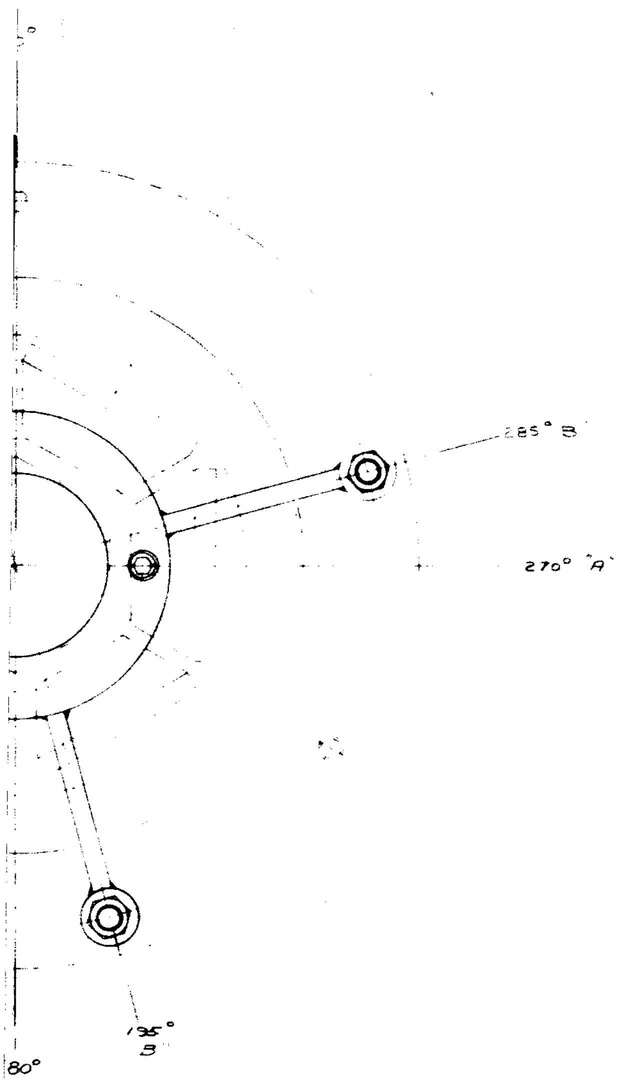
1.7.2 Selection of Bombardment Filament Size

The filaments of the electron bombardment unit should be capable of delivering the full power output of the JPL electron bombardment power supply


550-1000 SH. 1
305
A
304
303
302
301
306
307
308
"B"
'B
15°
A
90°
105°
B
150°
"A"

#1

REV	DESCRIPTION
4	[illegible]



FIGUR

7	SEE FIXTURE LAYOUTS (3090, 3190
6	UNK = UNKNOWN N D = NO DRAWING
5	DOTTED LINES INDICATE ROUGH OR
4	ALL MATING CORNERS & FILLETS A
3	MAX. PERMISSABLE TAP DRILL DEPTH THREAD DEPTHS ARE SHOWN
2	SECTION LOCATIONS DEFINED BY LET
1	NOTES 2 THRU 7 APPLY UNLESS OT

NOTES

DESIGN FINALIZED	DATE	INIT.
		?B

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
1																
2																
V																
ll																
⊥																

#2

	DATE	BY	APPR
	-65		

RE 3c

308	NO		2	S.S.	5/16 FLAT WASHER
307	NO		2	S S	5/16 18 HEX NUT
306	B		4	S.S.	SUPPORT LEG
305	B		1	S S	SUPPORT RING
304	NO		3	S S	1/4-20 x [illegible]
303	A		6	Al_2O_3	INSULATOR
302	B		4	S.S	WEB
30	A		4	S.S.	WEB [illegible]
PART	SIZE	REV	REQ	MAT'L	NOTES

ETC.) FOR FIXTURE INFORMATION.
PROCURE FROM THIS L.O.
PRELIMINARY MACHINING.
E .015 X 45° CHFR. AND .010 R. RES.
AND MIN PERMISSABLE FULL

TER LOCATION AT END VIEW.
HERWISE SPECIFIED.

DATE	UNIT	DATE	UNIT	DATE	UNIT

T U V W Y Z

UNLESS OTHERWISE SPECIFIED

DECIMAL .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS .010 MAXIMUM
THREADS CLASS 2
⊕ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ± 0°5
2.0-4.0 RAD ± 0°5
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE FULL	FINISH
NEXT ASSY	SIMILAR TO

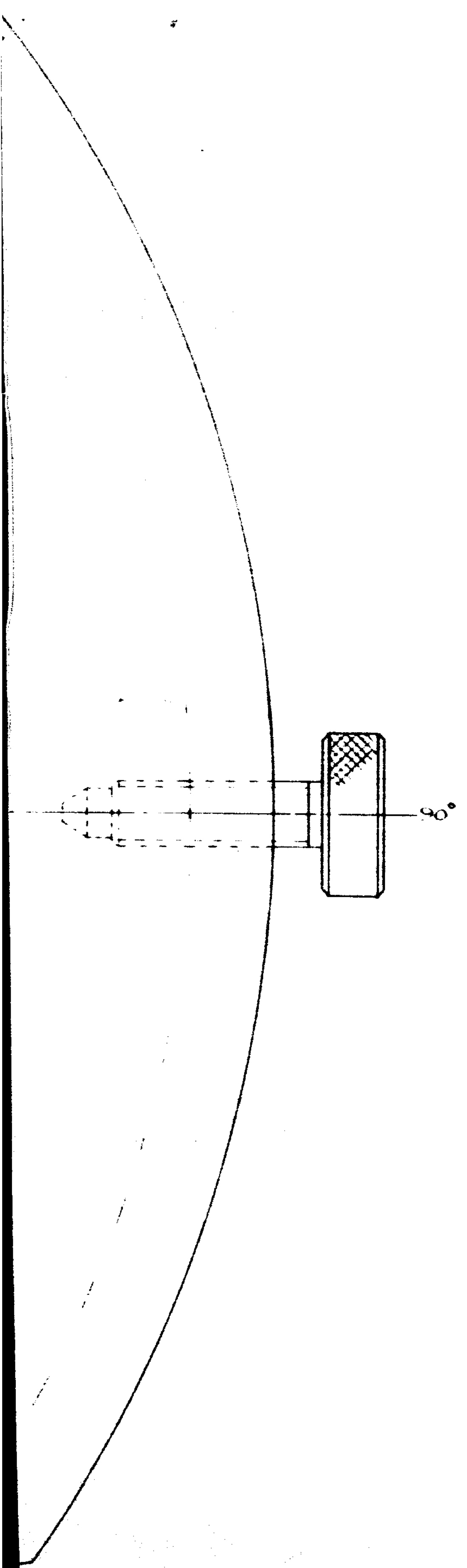
THERMO ELECTRON

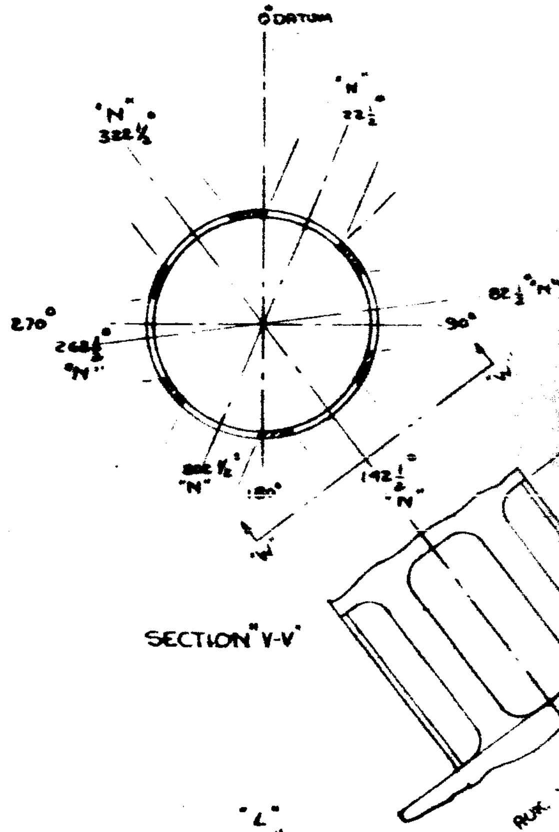
DRAWN	CHECKED	ENGINEER
[illegible]	[illegible]	

TITLE
[illegible] CONVERTER GENERATOR
(SUPPORT STRUCTURE

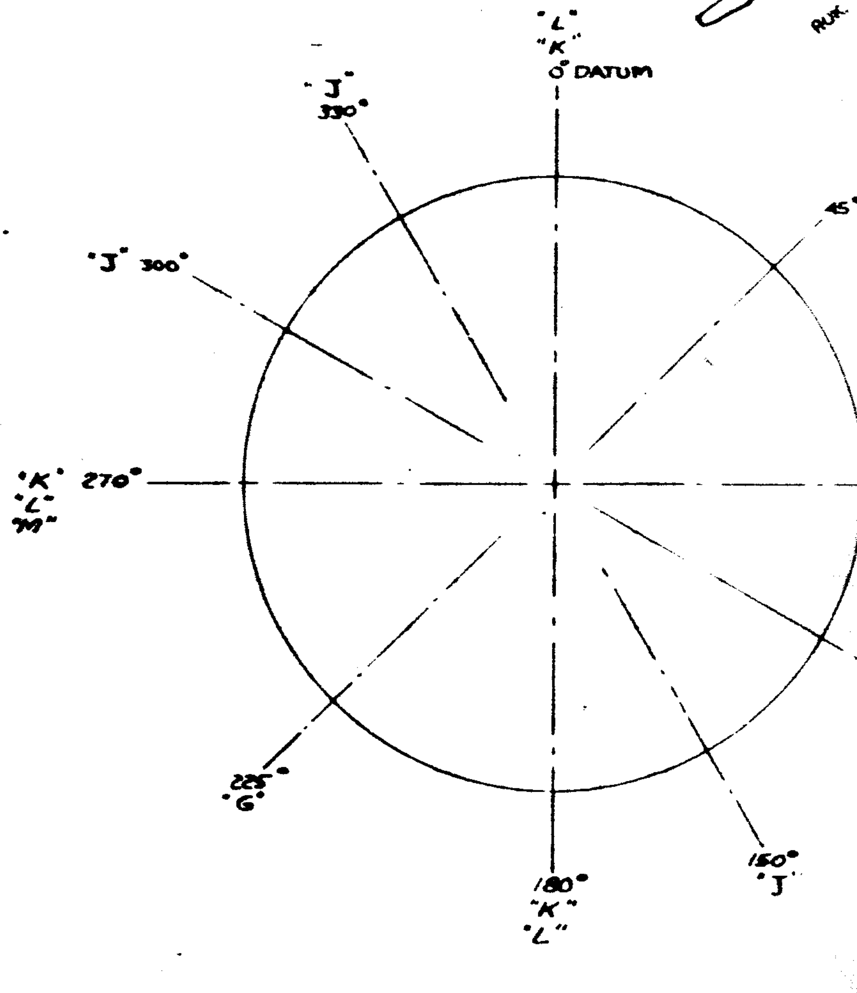
SIZE	DRAWING NUMBER	SHEET	REV
	550-1000	3	A

#3



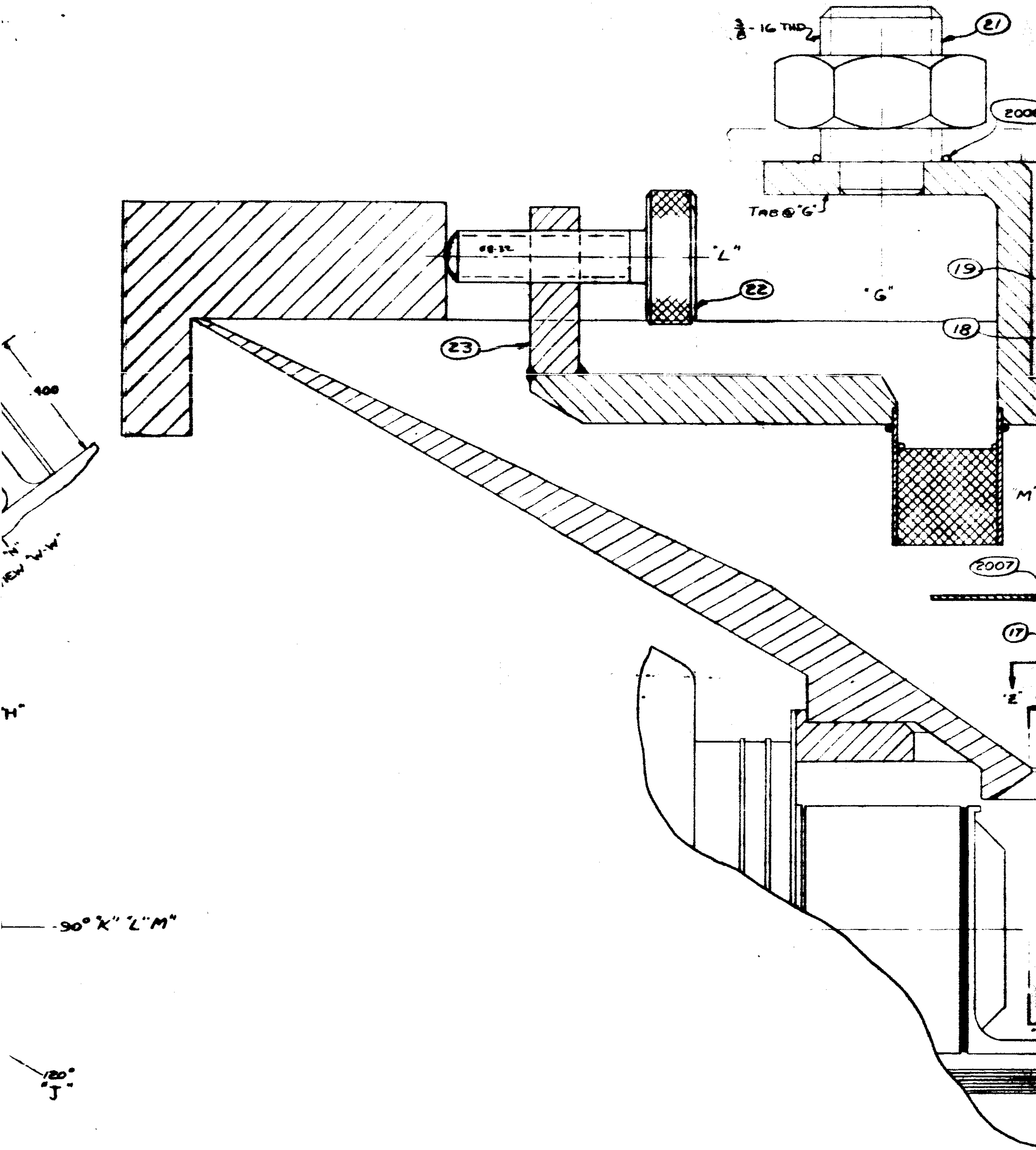


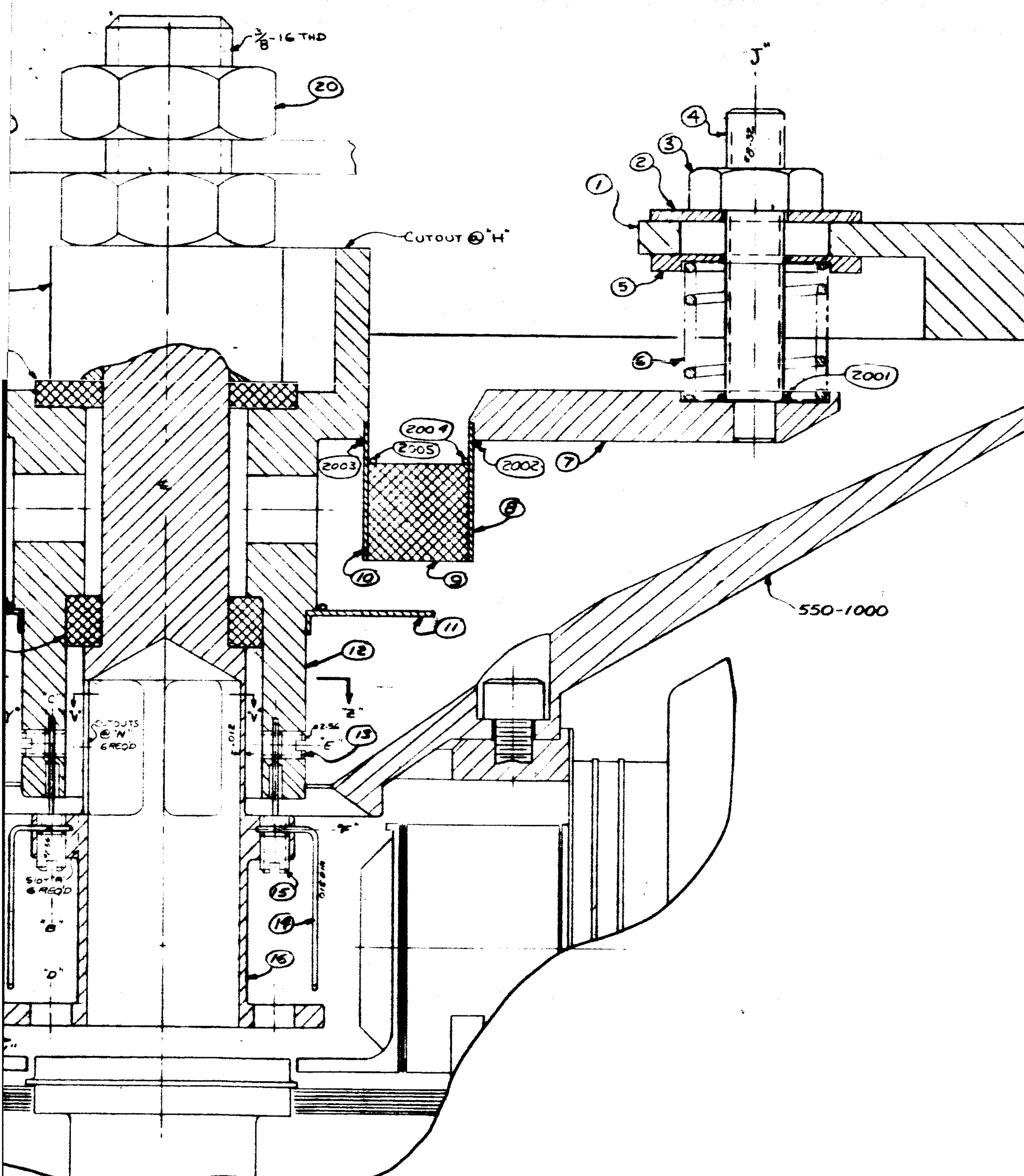
SECTION "V-V"



"ORIENTATION PLAN"

#4


3/8-16 THD
21
TAB @ "G"
"L"
22
"G"
19
18
23
.400
2007
17
"Z"
"H"
90° "K" "L" "M"
120°
"J"



3/8-16 THD
20
CUTOUT @ "H"
J"
4
3
2
1
5
6
2001
2004
2005
2003
2002
7
8
10
9
11
12
550-1000
"Z"
13
CUTOUTS @ "N" 6 REQ'D
SLOT "A" 6 REQ'D
"B"
"D"
15
14
16

PART	SIZE	REQ	LOC	MAT'
2001	ND	4		
2002	ND	1		
2003	ND	1		
2004	ND	1		
2005	ND	1		
2006	ND	1		
2007	ND	1		

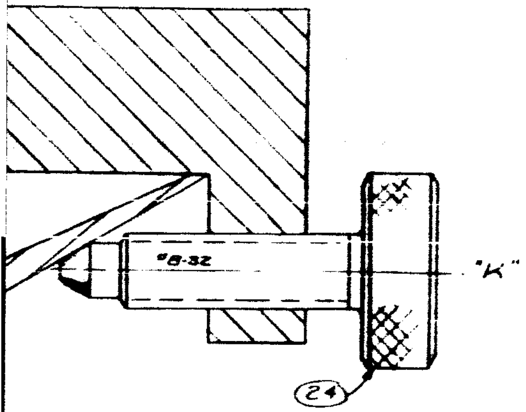


FIGURE 2

7 SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE
6 UNK = UNKNOWN N.D = NO DRAWING, PROCURE FROM TH
5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACH
4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR.
3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSA
THREAD DEPTHS ARE SHOWN.
2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT E
1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED

NOTES

DESIGN FINALIZED	DATE	INIT.	DATE	INIT.	DATE

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	Y	Z
1		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									
2																						
V																						✓
‖																						
⊥																						
◎																						

#17

	NOTES
BRAZES	
	.030 DIA. WIRE
	.030 [illegible]
	.030 DIA. WIRE
	.030 DIA WIRE
	.030 DIA WIRE
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	.030 DIA WIRE

INFORMATION.
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AND .010 R. RES.
LE FULL
D VIEW.

INT.	DATE	INIT.

PART	SIZE	REV	REQ	MAT'L	NOTES
24			4	S.S	CLAMP THUMB SCREW.
23			4	S.S.	SUPPORT (ADJ. SCREW)
22			4	SS	TRAVERSE ADJUST SCREW
21			1	Ta	TERMINAL STUD
20	ND		3	S.S	3/8-16 HEX HD. JAM NUT
19			1	S.S	WASHER (LOCATING)
18			1	Al_2O_3	INSULATING WASHER
17			1	Al_2O_3	LOW VOLTAGE INSULATOR
16			1	Ta	FILAMENT SUPPORT CENTRAL
15			6	Ta-W	FILAMENT SET SCREW (LONG)
14			6	W	FILAMENT
13			6	Ta-W	FILAMENT SET SCREW (SHORT)
12			1	Ta	FILAMENT SUPPORT OUTER
11			1	Ta	METAL VAPOR SHIELD
10			1	DH142	INSULATOR FLANGE INNER.
9			1	Al_2O_3	HIGH VOLTAGE INSULATOR
8			1	DH142	INSULATOR FLANGE OUTER
7			1	S.S.	MOVABLE SUPPORT
6	ND		4	S.S	SEE # LC-036F-1 (SPRING)
5			4	S.S	SPRING RETAINER WASHER
4			4	S.S.	THREADED POST.
3	N.D		4	S.S.	#8-32 HEX HD NUT (HEIGHT ADJ)
2			4	S.S.	WASHER
1			1	S.S	MAIN SUPPORT RING

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS .010 MAXIMUM
THREADS: CLASS 2
DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0°5'
2.0-4.0 RAD. ±0°5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

DRAWN	CHECKED	ENGINEER
E.B. / B.K.	6-9-65	[illegible]

TITLE: ELECTRON BOMBARDMENT UNIT

SCALE: 5 x 1	FINISH:
NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
H	549-1000		

#8

55

of 3A at 1000 volts. This is an emission of 500 mA per filament. Since the length of each filament is 5.2 cm., and the corresponding emission length is estimated at 2.5 cm., the emission current per unit of filament length should be 200 mA/cm.

Also, the filament supply current should not exceed one-sixth of the available 100 ampere filament current of the JPL filament power supply.

Figure 22 shows that for filament currents of less than 16 amperes, an emission current density of 200 mA/cm. is achieved with filaments having a diameter of about 0.4 mm or less, i.e., approximately 0.015 inch in diameter. The corresponding filament life at this maximum input condition is of the order of 300 hours. This is clearly a rather marginal value, particularly if any extended operation is required during outgassing of the generator prior to the actual runs. The condition was reviewed with the technical cognizant personnel at JPL, and it was agreed to relax the requirement that the maximum total filament current be less than 100 amperes to the extent required to achieve a design life of 2000 hours. Figure 22 then shows that the filament diameter should be 30 mils, with a filament current of 30 amperes for the emission of 200 mA per centimeter, and a filament voltage of 0.6 volts/cm which, for a filament length of 5.2 cm. is adequately within the 5 volt limit of the JPL power supply. The design condition is then:

Maximum Filament Current	180 amperes
Maximum Filament Voltage	3.2 volts
Maximum Bombardment Current	3 amperes
Bombardment Voltage	1000 volts
Minimum Filament Life	2000 hours
Filament Diameter	0.030 inch

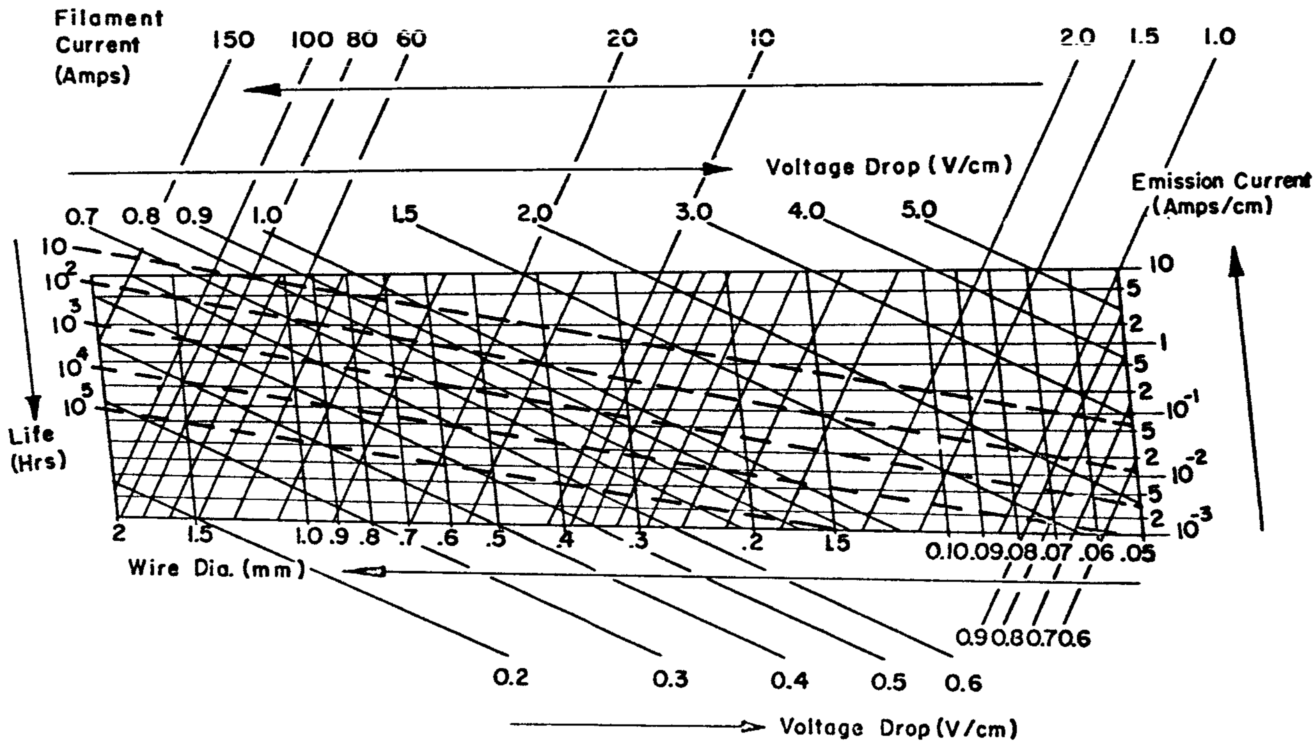


Figure 22. Tungsten Filament Characteristics (Kohl, "Materials and Techniques for Electron Tubes", p. 278)

1.7.3 Control of Heat Losses in Electron Bombardment Structure

As discussed in Section 1.7.1, the heat losses of the electron bombardment support structure can be minimized by providing the central filament support structure with an adequate heat resistance. The heat loss through this resistance can be adequately estimated with the basic conduction equation:

$$Q = ks \Delta T/L$$

To avoid overheating the portion of the filament support that is within the cavity, an upper temperature limit of $1800^{\circ}K$ can be specified for it. Assuming a maximum temperature of $800^{\circ}K$ on the remainder of the support structure, $\Delta T = 1000^{\circ}K$. The length of the heat resistance element as selected in the design is 1.0 cm. Assuming a thermal conductivity for tantalum of 0.70 watts/cm-deg K, and for the diameter of 1.2 cm. of the heat resistance element, the heat loss becomes:

$$Q = 0.7 \times \pi \times 1.2 \times 1000 \times t = 2640 \text{ t watts}$$

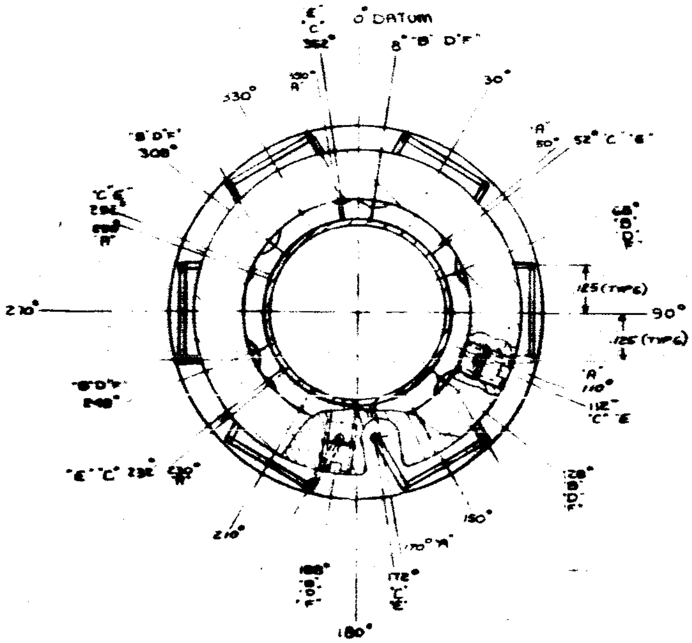
where t is the wall thickness in centimeters. If i is expressed in mils,

$$Q = 6.60 \text{ t watts.} \tag{15}$$

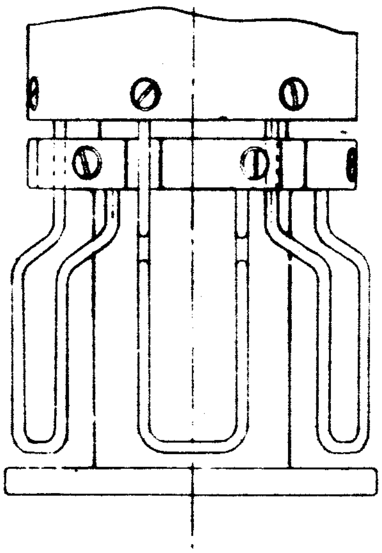
The heat actually received by the portion of the filament structure exposed to the interior of the cavity is essentially equal to the radiant heat transfer corresponding to the surface area of the filament support which is approximately 18 watts per sq. cm. for 10 sq. cm., or 180 watts. From Equation (18) it is then seen that the thickness of the resistance heat transfer element must then be approximately 27 mils.

1.8 Final Design of Electron Bombardment Unit

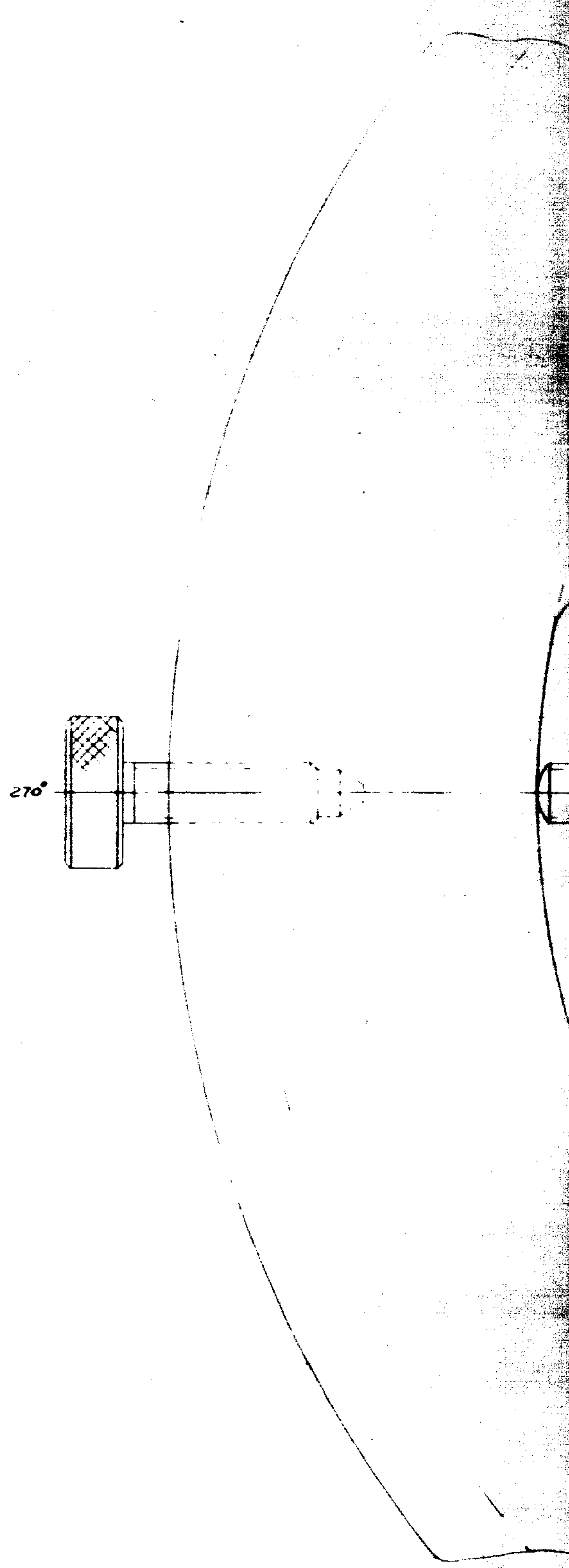
Figure 23, Dwg. 549-1000, Revision A, shows the layout of the electron bombardment unit as finally approved by JPL. The layout is identical to that of Figure 21, except that the filament size has been increased to 0.030 inch

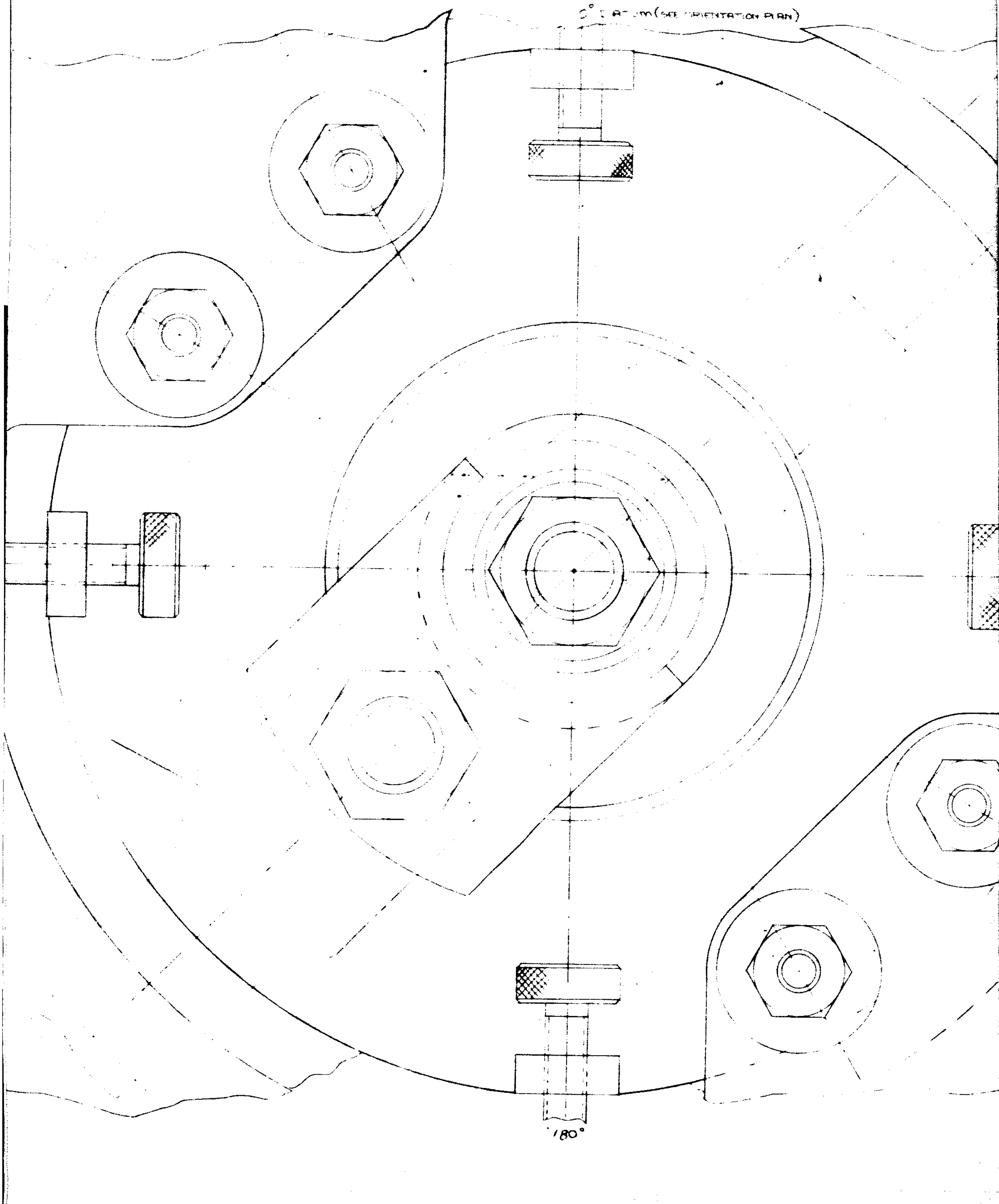


SECTION "Z-Z"

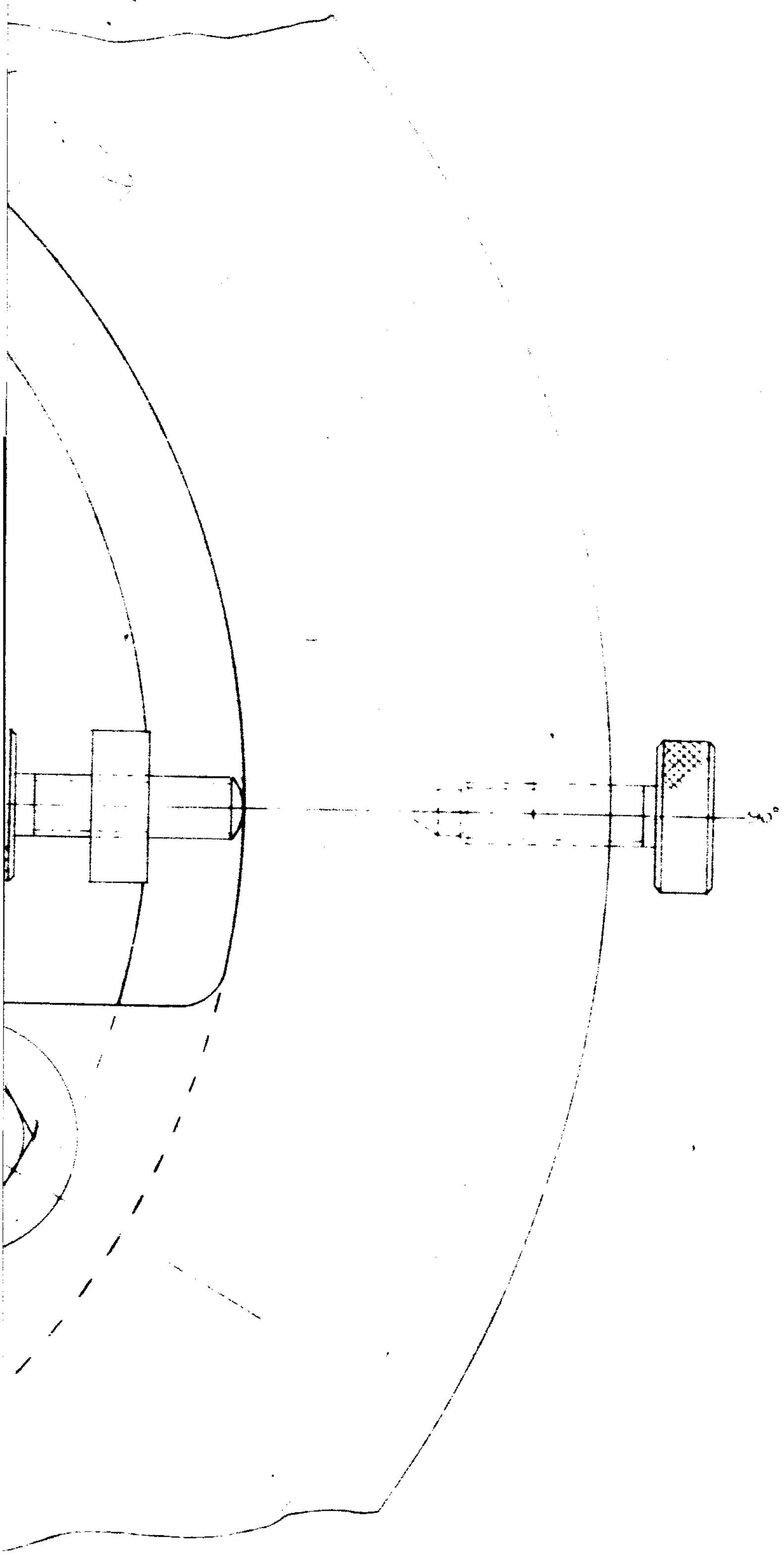


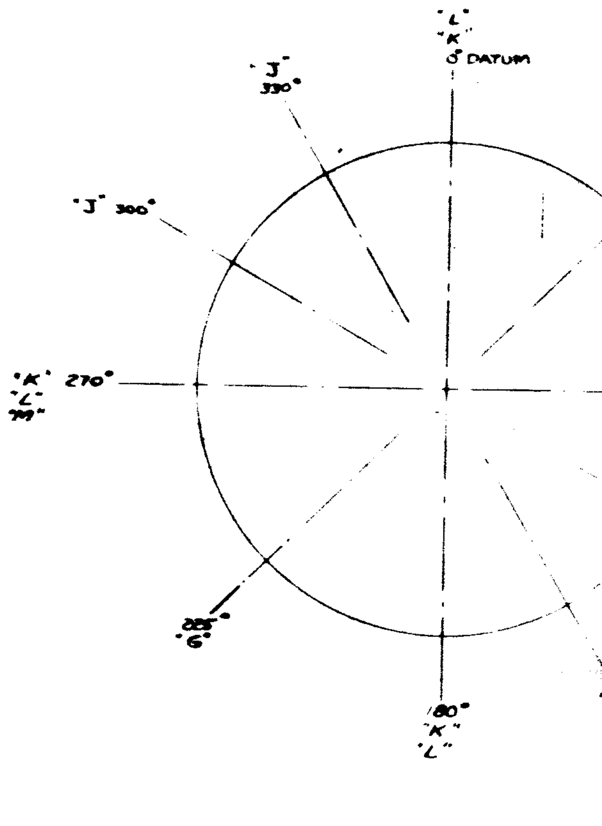
SECTION "Y-Y"





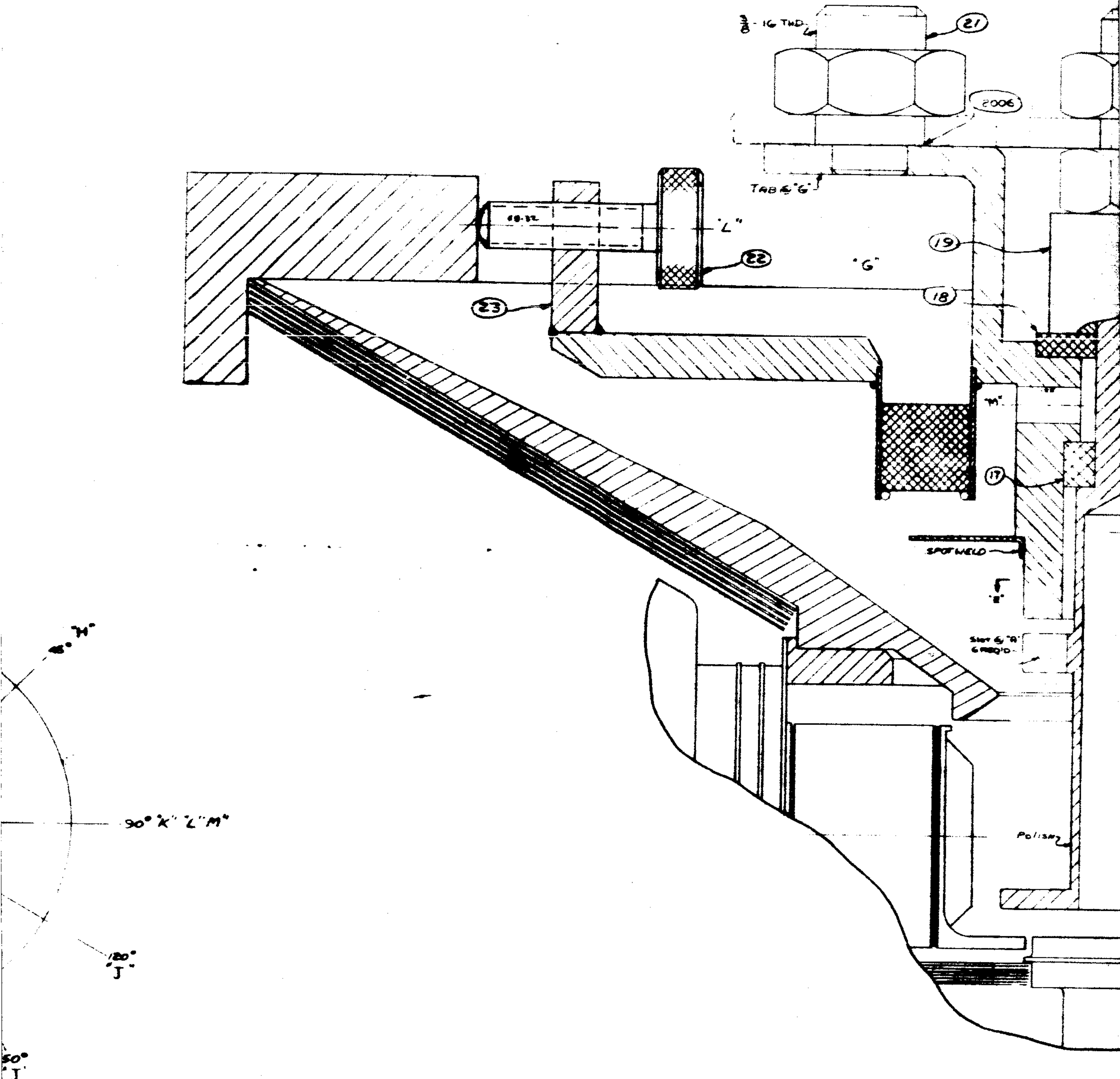
#2



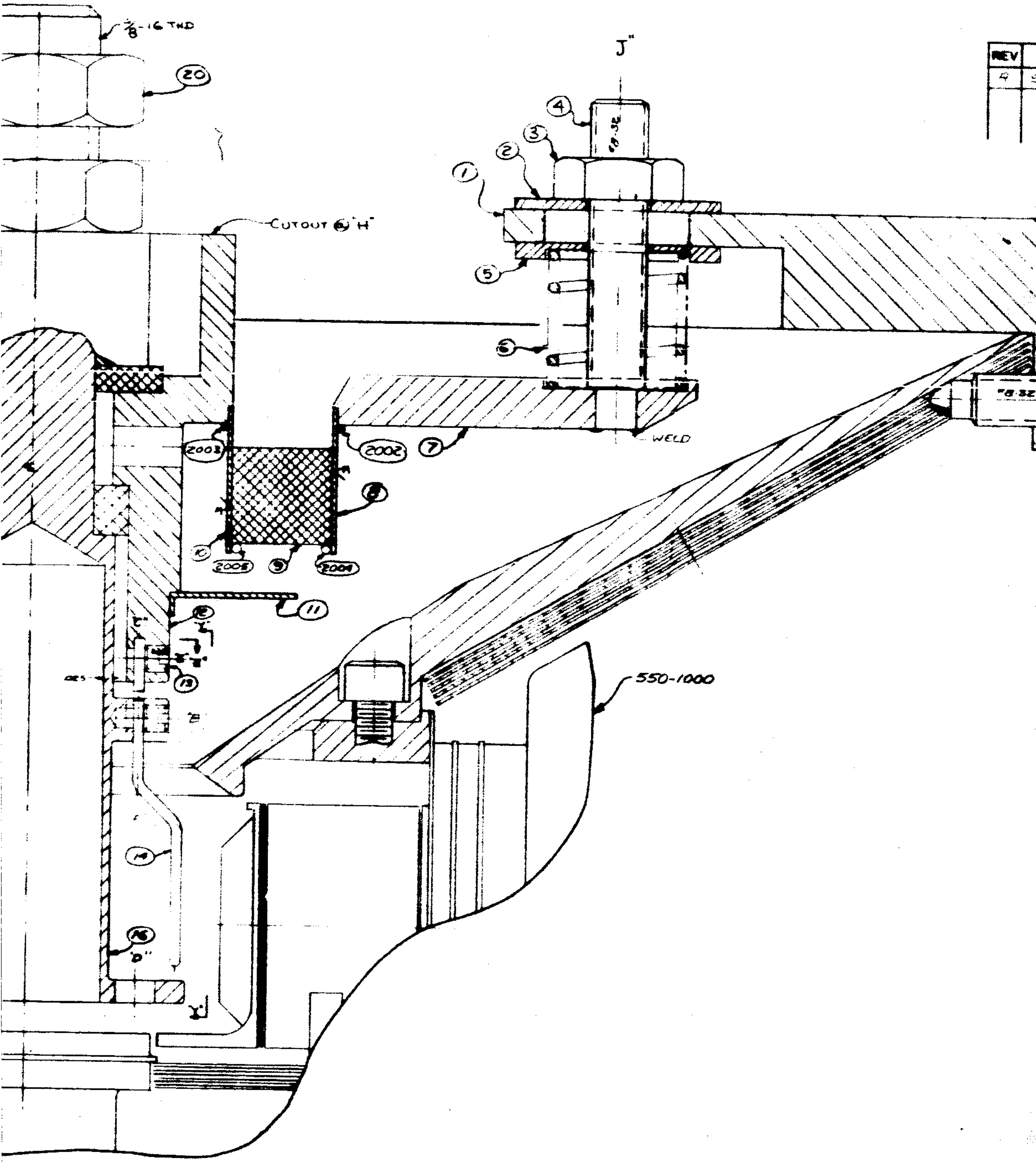


"ORIENTATION PLAN"

#3



21
2006
TAB & "G"
"L"
22
"G"
19
18
23
"M"
17
SPOTWELD
Polish
"H"
90° "K" "L" "M"
120°
"J"
150°
"J"



5/8-16 THD
20
J"
4
3
2
1
5
6
CUTOUT @ "H"
8-32
2003
2002
7
WELD
8
10
2005
9
2004
11
12
13
550-1000
14
15
"D"
REV
4

#5

DESCRIPTION	DATE	BY	APPR
E: OBS L.O. 8-3 65)	8-4-65	MN	

PART	SIZE	REQ	LOC	MAT'L	NOTES
BRAZES					
2002	ND	1		Cu	.030 DIA WIRE
2003	ND	1		Cu	.030 DIA WIRE
2004	ND	1		Cu	.030 DIA WIRE
2005	ND	1		Cu	.030 DIA WIRE
2006	A	1		FE 75	.003 THK WASHER

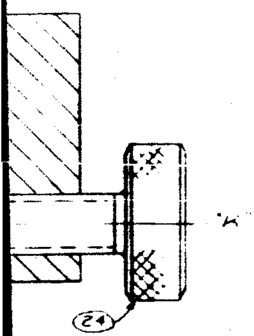


FIGURE 23

PART	SIZE	REV	REQ	MAT'L	NOTES
24	B		4	S.S	CLAMP THUMB SCREW.
23	B		4	S.S.	SUPPORT (ADJ. SCREW)
22	B		4	SS	~~TORQUE~~ ADJUST SCREW
21	B		1	Ta	TERMINAL STUD
20	ND		3	S.S	3/8-16 HEX HD JAM NUT
19	A		1	S S	WASHER (LOCATING)
18	B		1	Al_2O_3	INSULATING WASHER
17	B		1	Al_2O_3	LOW VOLTAGE INSULATOR
16	D		1	Ta	FILAMENT SUPPORT CENTRAL
15					
14	B		6	W	FILAMENT
13	A		12	Ta-W	FILAMENT SET SCREW (SHORT)
12	D		1	Ta	FILAMENT SUPPORT OUTER
11	B		1	Ta	METAL VAPOR SHIELD
10	B		1	DH 142	INSULATOR FLANGE INNER.
9	C		1	Al_2O_3	HIGH VOLTAGE INSULATOR
8	B		1	DH 142	INSULATOR FLANGE OUTER
7	C		1	S.S.	MOVABLE SUPPORT
6	ND		4	S.S	SEE #LC 036F-1 (SPRING)
5	A		4	S.S	SPRING RETAINER WASHER
4	B		4	S.S.	THREADED POST.
3	N.D.		4	S.S.	#8-32 HEX HD NUT (HEAVY)
2	A		4	S.S	WASHER
1	D		1	S S	MAIN SUPPORT RING

8 $\sqrt{}$ = Mo-Ti & Ni Plate .0006 THK
7 SEE FIXTURE LAYOUTS (3000, 3100 ETC.) FOR FIXTURE INFORMATION.
6 UNK = UNKNOWN N.D. = NO DRAWINGS, PROCURE FROM THIS L.O.
5 DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4 ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3 MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2 SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1 NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

DESIGN FINALIZED	DATE	INIT.	DATE	INIT.	DATE	INIT.	DATE	INIT.
	6-1-65	FB						

A B C D E F G H J K L M N P R S T U V W Y Z

UNLESS OTHERWISE SPECIFIED

DECIMAL .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAXIMUM
THREADS: CLASS 2
⊕ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ±0°1'
2.0-4.0 RAD ±0°5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

DRAWN	CHECKED	ENGINEER
F.B. MN	8-3-65	

TITLE ELECTRON BOMBARDMENT UNIT

SCALE 5/1

FINISH

NEXT ASSY

SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
H	549-1000		A

#6

from a previous value of 0.015 inch, as explained in Section 1.7.2, and the point of attachment of the lower filament ends has been displaced so as to lay outside the generator cavity to avoid overheating. The inner filament support, part No. 16, which was originally shown with six cut-outs in a view "V-V", no longer includes these cut-outs because the thermal calculation of Section 1.7.3 indicates that these are unnecessary.

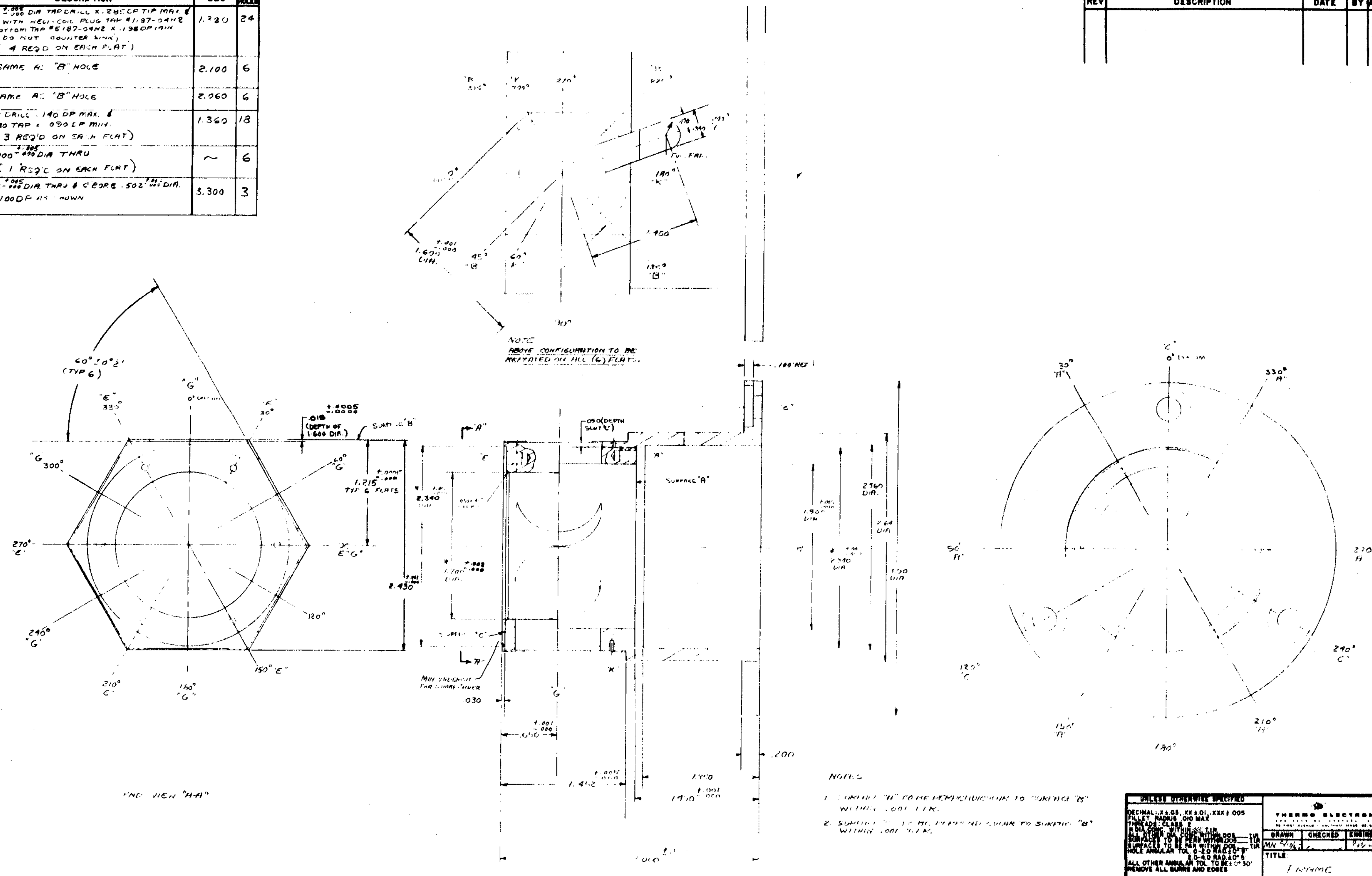
2.1 Detailed Mechanical Drawings for the Generator

550-001 to

550-2001

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"B"	.119 $^{+.005}_{-.000}$ DIA TAP DRILL X .285 DP TIP MAX & TAP WITH HELI-COIL PLUG TAP #1187-04H2 & BOTTOM TAP #5187-04H2 X .198 DP MIN (DO NOT COUNTER SINK) (4 REQ'D ON EACH FLAT)	1.?20	24
"A"	SAME AS "B" HOLE	2.100	6
"E"	SAME AS "B" HOLE	2.060	6
"K"	TAP DRILL .140 DP MAX. & #0-80 TAP X .090 DP MIN. (3 REQ'D ON EACH FLAT)	1.360	18
"G"	1.000 $^{+.005}_{-.000}$ DIA THRU (1 REQ'D ON EACH FLAT)	~	6
"C"	.125 $^{+.005}_{-.000}$ DIA THRU & C'BORE .502 $^{+.00?}_{-.00?}$ DIA. X .100 DP AS SHOWN	3.300	3

REV	DESCRIPTION	DATE	BY	APPR



NOTES

1. SURFACE "A" TO BE PERPENDICULAR TO SURFACE "B" WITHIN .001 T.I.R.
2. SURFACE "C" TO BE PERPENDICULAR TO SURFACE "B" WITHIN .001 T.I.R.

MAT'L	REQ
Mo	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.05, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAX
THREADS: CLASS 2
⌀ DIA CONC. WITHIN .002 T.I.R.
ALL OTHER DIA CONC. WITHIN .005 — T.I.R.
SURFACES TO BE PERP WITHIN .005 — T.I.R.
SURFACES TO BE PAR WITHIN .005 — T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0°8'
2.0-4.0 RAD. ±0°5'
ALL OTHER ANGULAR TOL. TO BE ±0°30'
REMOVE ALL BURRS AND EDGES

SCALE: 2X1 | FINISH:
NEXT ASSY. | SIMILAR TO

THERMO ELECTRON

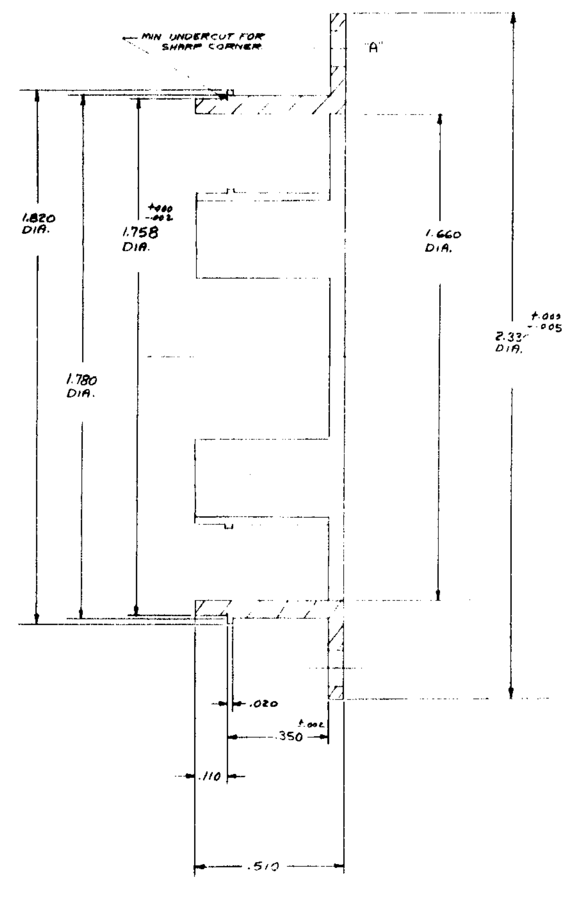
DRAWN	CHECKED	ENGINEER
MN		

TITLE: FRAME

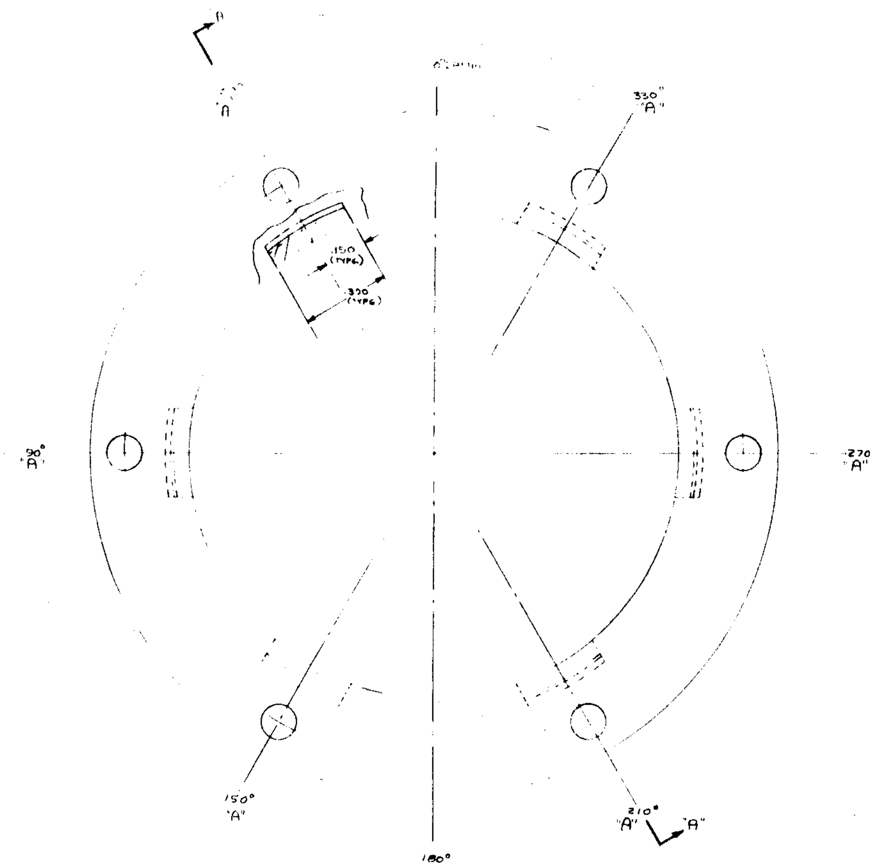
SIZE	DRAWING NUMBER	SHEET	REV
D	001		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"A"	.125 $^{+.002}_{-.000}$ DIA. THRU	2.100	6

REV	DESCRIPTION	DATE	BY	APPR



VIEW "A-A"



UNLESS OTHERWISE SPECIFIED
DECIMAL: .X ±.05, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAX
THREADS: CLASS 2
DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

MAT'L	REQ	SCALE: 2/1	FINISH: 63
Nb	1	NEXT ASSY	SIMILAR TO

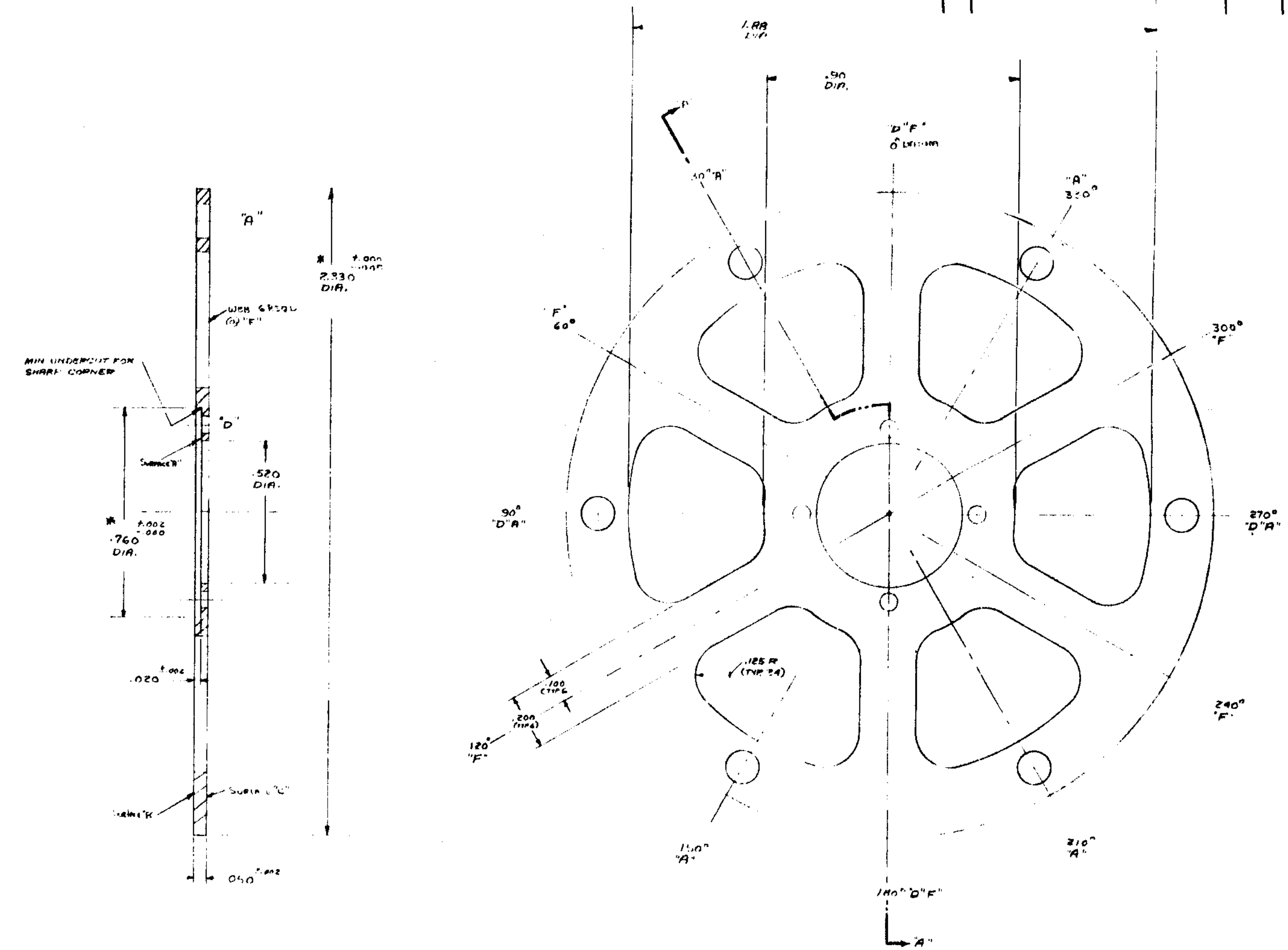
DRAWN	CHECKED	ENGINEER
MN 9/11/68		

TITLE: REAR SHIELD HOLDER

SIZE	DRAWING NUMBER	SHEET	REV
D	550-002		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"A"	$.125^{+.005}_{-.000}$ DIA THRU	2.100	6
"D"	$.070^{+.003}_{-.000}$ DIA THRU	.690	4

REV	DESCRIPTION	DATE	BY	APPR



NOTE:
SURFACE "B" & "C" TO BE FLAT & PARALLEL TO SURFACE "A" WITHIN .0005 T.I.R.

UNLESS OTHERWISE SPECIFIED
DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS .010 MAX
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

DRAWN	CHECKED	ENGINEER
MW		

TITLE: HEAT CAVITY PIECE SUPPORT

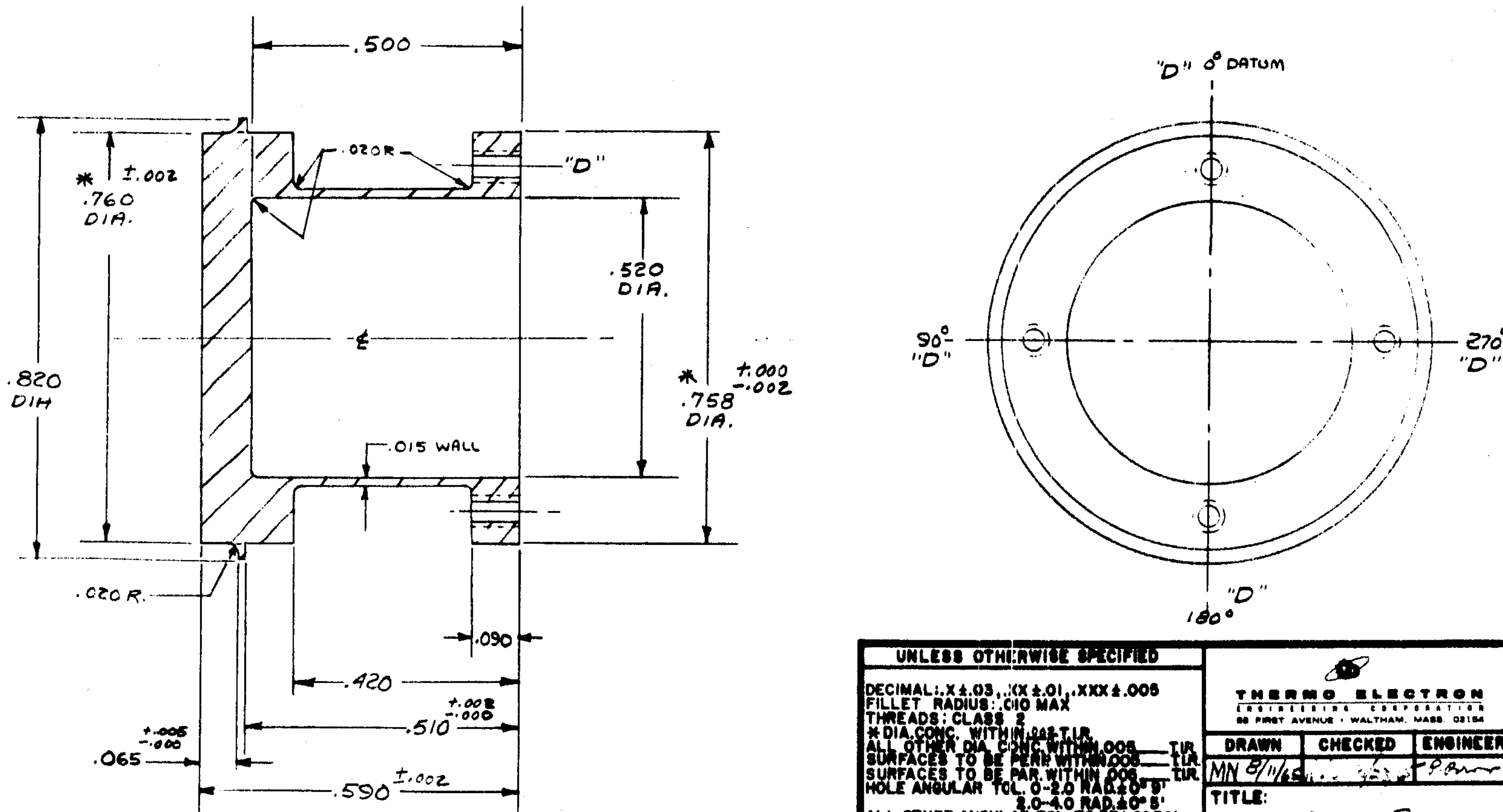
MAT'L	REQ	SCALE	FINISH
Nb	1	2/1	

NEXT ASSY. | SIMILAR TO

SIZE: D | DRAWING NUMBER: [illegible]

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"D"	#0-80 THD. THRU	.690	4

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN .002 T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
W	/

SCALE: 5×1	FINISH: 63RMS
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

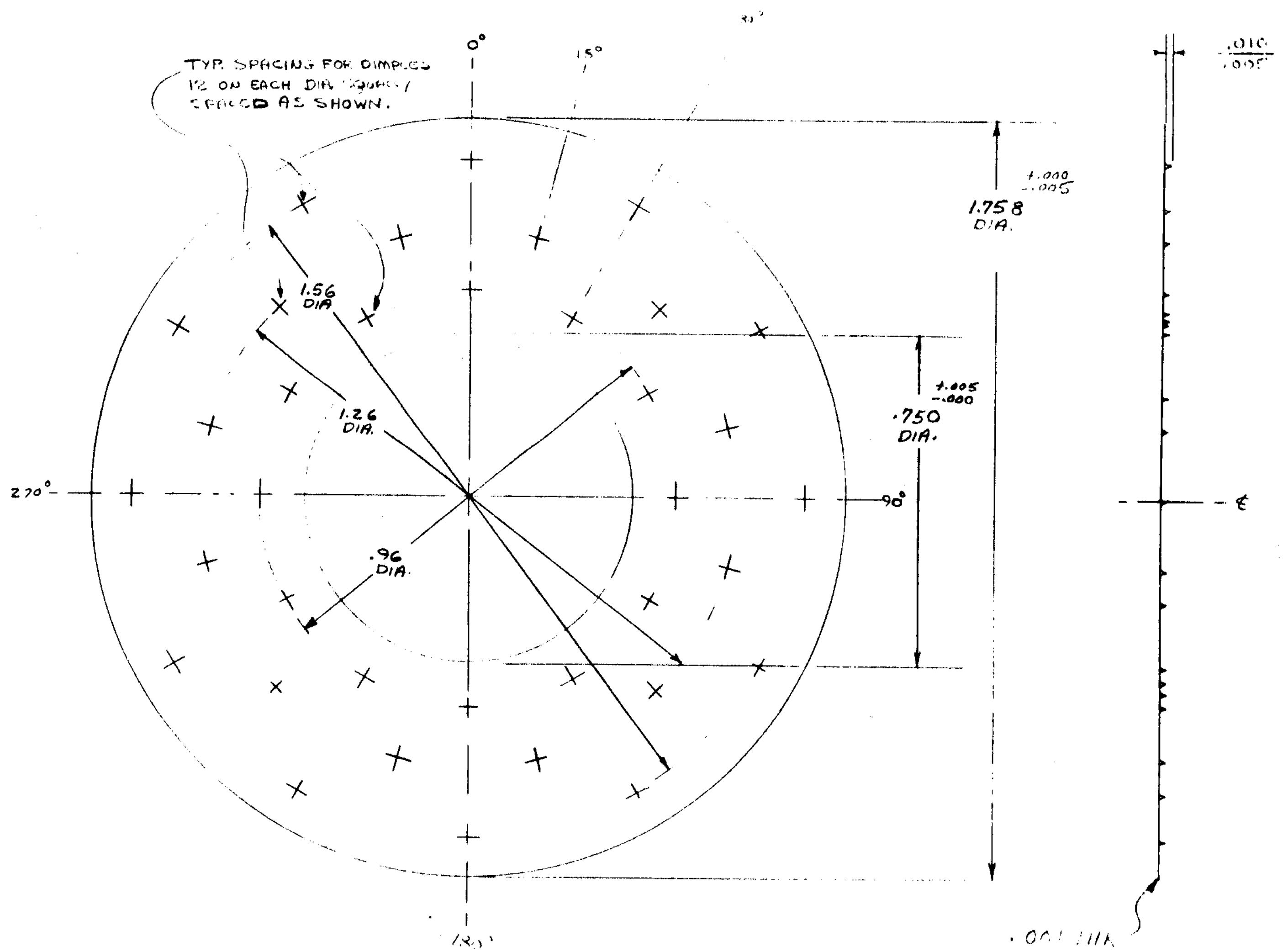
DRAWN	CHECKED	ENGINEER
MN 8/11/65	[illegible]	[illegible]

TITLE: REAR CAVITY PIECE

SIZE	DRAWING NUMBER	SHEET	REV
B	550-004		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED
DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
*DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

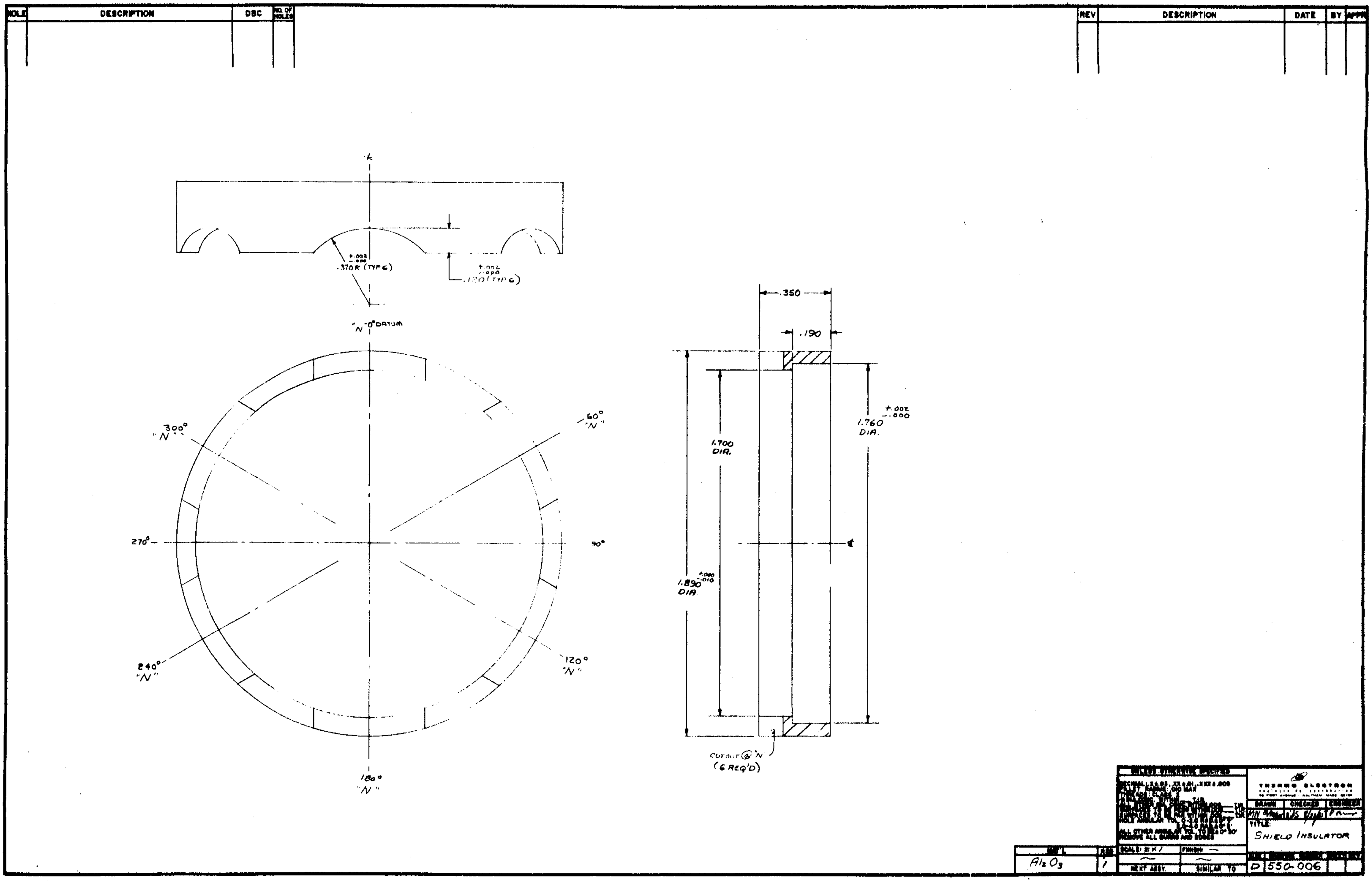
THERMO ELECTRON ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

DRAWN	CHECKED	ENGINEER
MN 9/17/6		

TITLE: REAR SHIELD

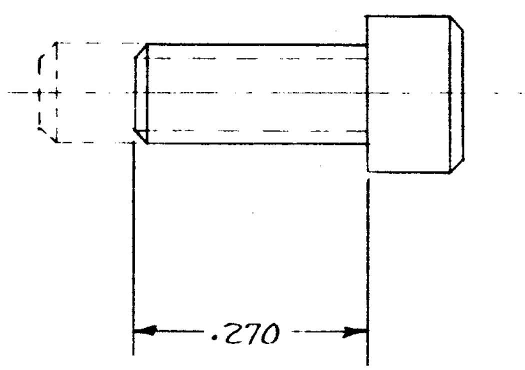
MAT'L	REQ	SCALE: 5×1	FINISH:
Mo	6	NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
C	550 005		



HOLE
DESCRIPTION
DBC
NO. OF HOLES
REV
DESCRIPTION
DATE
BY
APPR
.370 R (TYP 6)
.120 (TYP 6)
"N" 0° DATUM
300° "N"
60° "N"
270°
90°
240° "N"
120° "N"
180° "N"
.350
.190
1.700 DIA.
1.760 DIA.
1.890 DIA
CUTOUT @ "N" (6 REQ'D)
THERMO ELECTRON
DRAWN
CHECKED
ENGINEER
TITLE:
SHIELD INSULATOR
MAT'L
Al_2O_3
SCALE
FINISH
NEXT ASSY.
SIMILAR TO
D 550-006

REV	DESCRIPTION	DATE	BY	APPR



MADE FROM #4-40 SOC. HD. CAP SCREW X .375 LNG.

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
✱ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/17/65	RGL 8/19/65	[illegible]

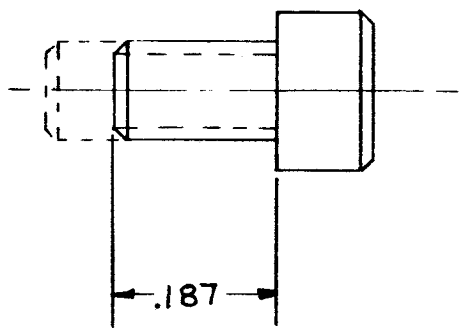
TITLE: Screw (RE-OP)

SCALE: 5 X 1	FINISH: —
—	—
NEXT ASSY.	SIMILAR TO

MAT'L	REQ
SS	6

SIZE	DRAWING NUMBER	SHEET	REV
A	550-007		

REV	DESCRIPTION	DATE	BY	APPR



MADE FROM #4-40 SOC. HD. CAP SCREW X .250 LNG.

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/17/65	RBS 8/19/65	[illegible]

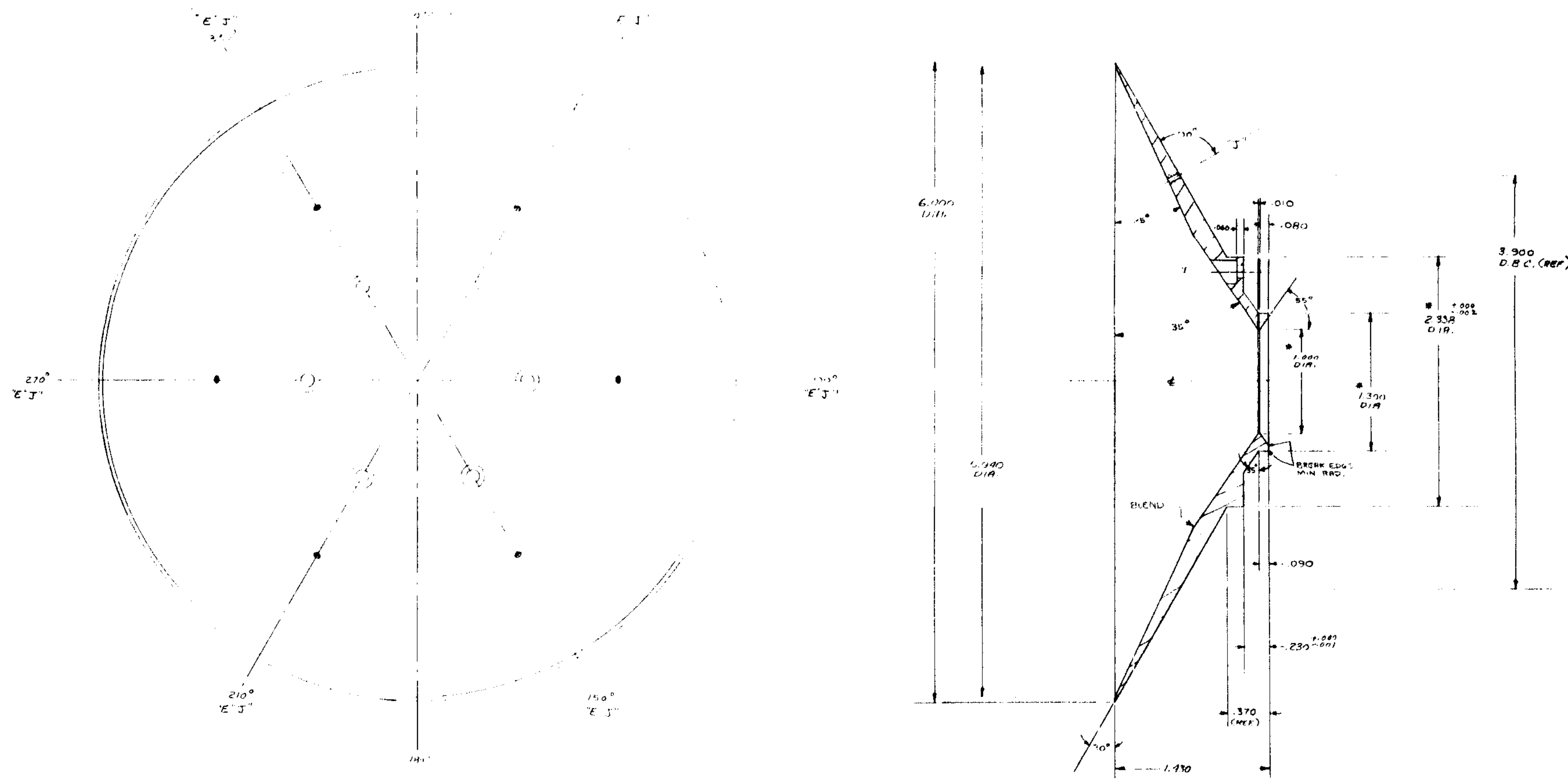
TITLE: Screw (RE-OP)

MAT'L	REQ	SCALE: 5 X 1	FINISH: —
S.S.	24	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-008		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"E"	.122 DIA THRU & C BORE .220 DIA TO DEPTH SHOWN	2.060	6
"J"	#0-80 TAP THRU AS SHOWN.	3.900	6

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS .010 MAX
THREADS: CLASS 2
DIA. CONC. WITHIN .002 T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP WITHIN .005 T.I.R.
SURFACES TO BE PAR WITHIN .005 T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ±0° 8'
2.0-4.0 RAD ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON

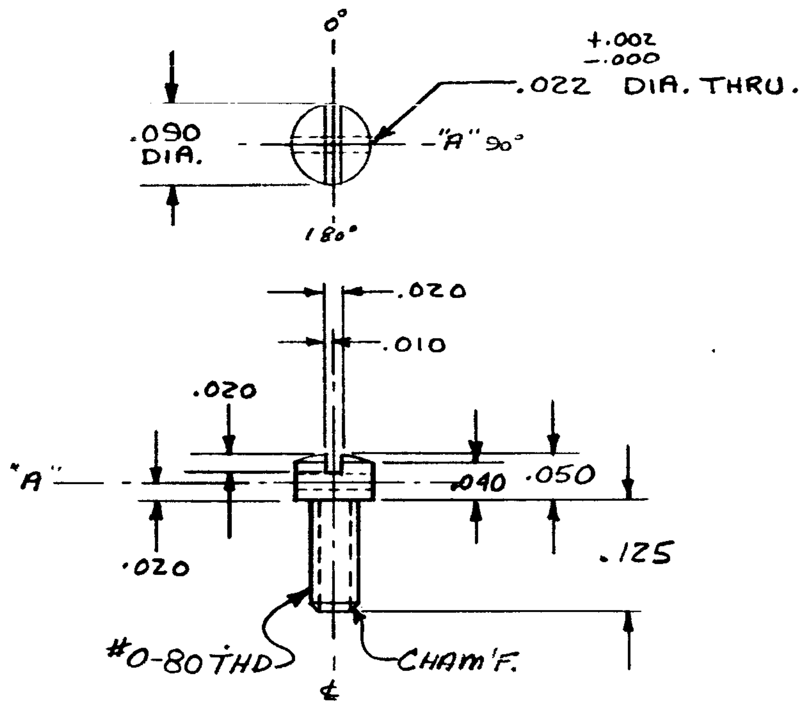
MAT'L	REQ	SCALE: 2X1	FINISH:
W	/		
		NEXT ASSY	SIMILAR TO

DRAWN	CHECKED	ENGINEER
MN		

TITLE: FRONT CONE

SIZE	DRAWING NUMBER
D	550-005

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
✱ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

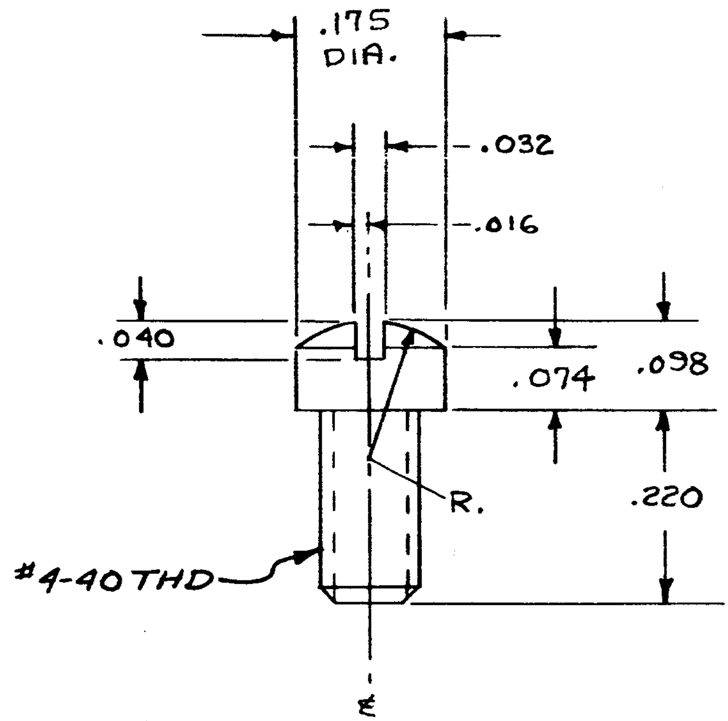
DRAWN	CHECKED	ENGINEER
MN 8/17/65	RBS 8/19/65	R. B. [illegible]

TITLE: HIGH TEMP. SCREW

MAT'L	REQ	SCALE: 5×1	FINISH: —
Ta-W	4	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-010		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

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ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

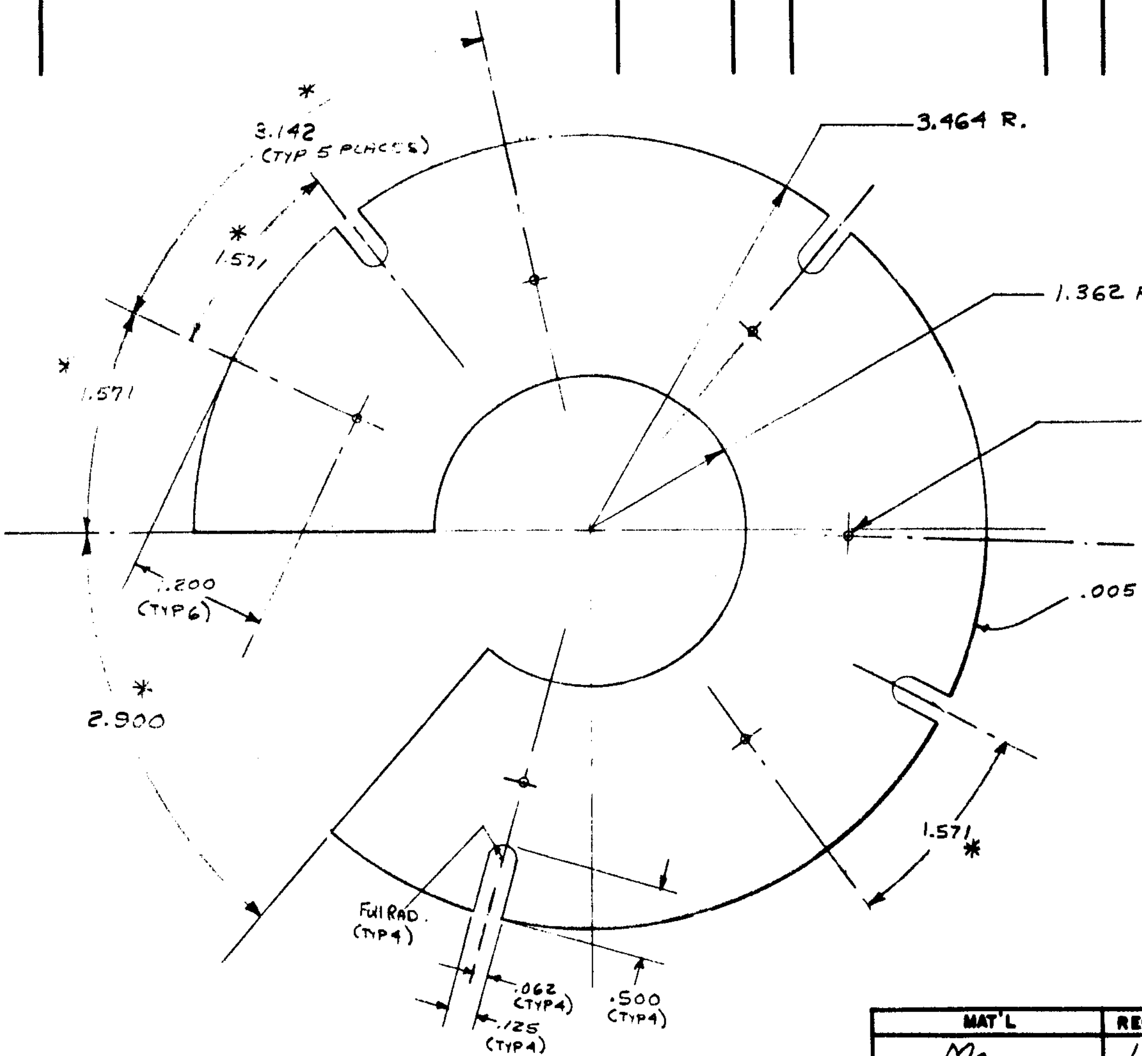
DRAWN	CHECKED	ENGINEER
MN 8/17/65	[illegible] 8/9/65	[illegible]

TITLE: *High Temp Screw*

MAT'L	REQ	SCALE: 5 x 1	FINISH: —
Ta-W	6	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-012		

HOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR



1. TOLERANCE NOT TO BE CUMULATIVE.
2. DIMENSIONS WITH (*) ARE TO BE TAKEN FROM OUTER CIRCUMFERENCE

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
[redacted]
ALL OTHER DIA. CONC. WITHIN .005 — T.I.R.
SURFACES TO BE PERP. WITHIN .005 — T.I.R.
SURFACES TO BE PAR. WITHIN .005 — T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ	SCALE: FULL	FINISH:
Mo	1	—	—
		NEXT ASSY.	SIMILAR TO

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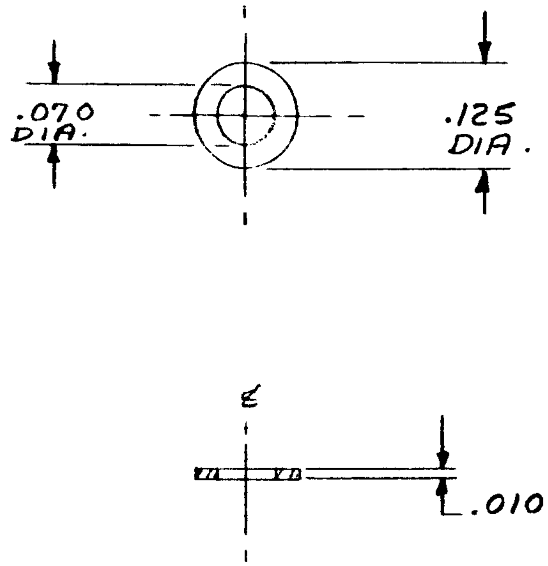
DRAWN	CHECKED	ENGINEER
MN 8/11/65	[illegible]	[illegible]

TITLE: Cone Shield #1

SIZE	DRAWING NUMBER	SHEET	REV
B	550-014		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

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DRAWN	CHECKED	ENGINEER
MN 8/17/65	RBS 8/19/65	P.B.

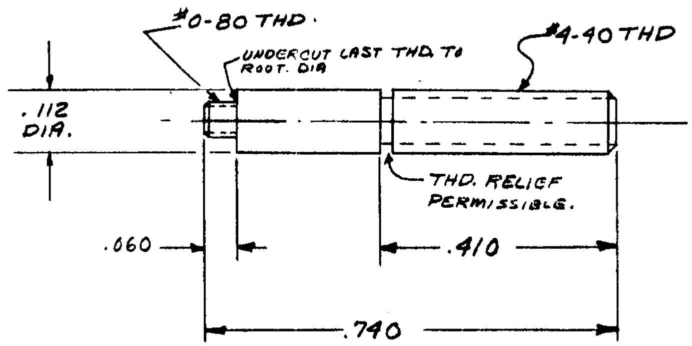
TITLE: WASHER

MAT'L	REQ	SCALE: 5×1	FINISH: 63 RMS
Mo	30	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-015		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

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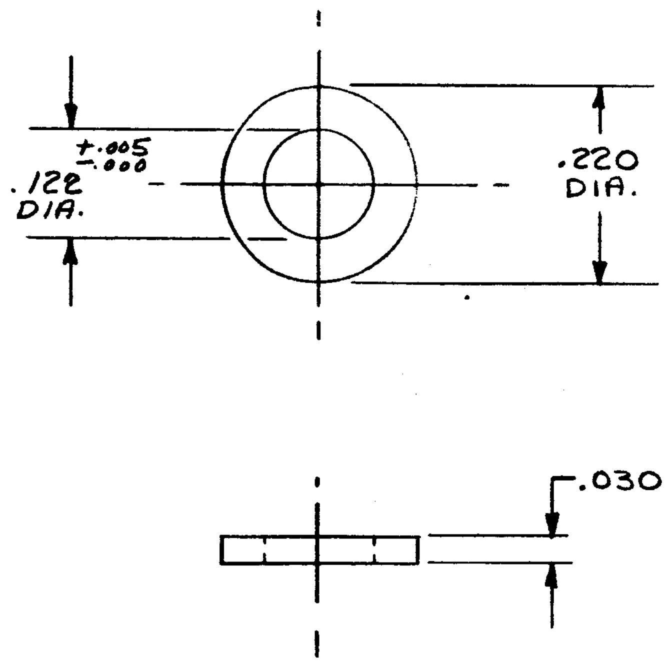
DRAWN	CHECKED	ENGINEER
MN 8/17/65	[illegible]	

TITLE: STUD

MAT'L	REQ	SCALE: 5 X 1	FINISH: 63 RMS
S.S.	18	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
B	550-017		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED
DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005 FILLET RADIUS: .010 MAX THREADS: CLASS 2 * DIA. CONC. WITHIN ___ T.I.R. ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R. SURFACES TO BE PERP. WITHIN .005 ___ T.I.R. SURFACES TO BE PAR. WITHIN .005 ___ T.I.R. HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9' 2.0-4.0 RAD. ±0° 5' ALL OTHER ANGULAR TOL. TO BE ±0° 30' REMOVE ALL BURRS AND EDGES

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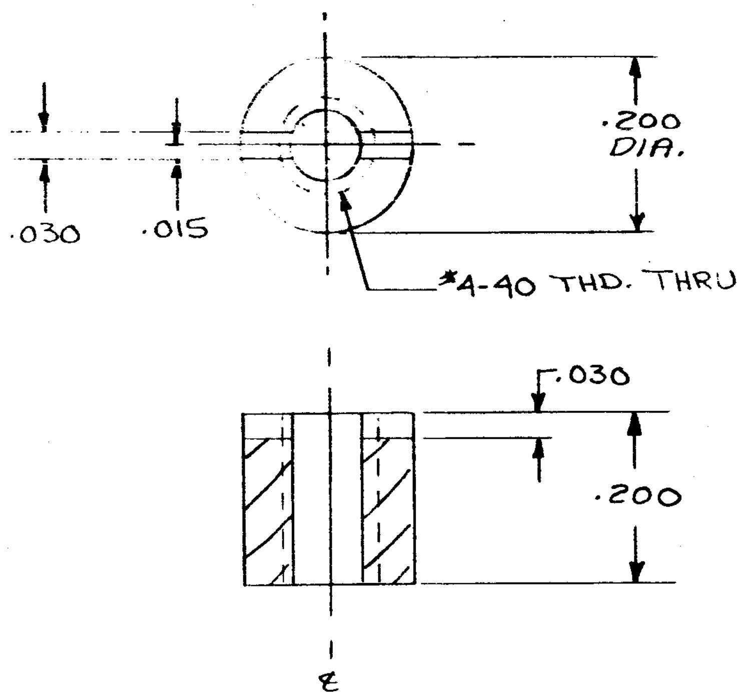
DRAWN	CHECKED	ENGINEER
MN 8/17/65	RBS 8/19/65	R. Brown

TITLE: WASHER

MAT'L	REQ	SCALE: 5×1	FINISH: 63RMS
		—	—
SS	18	NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-018		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

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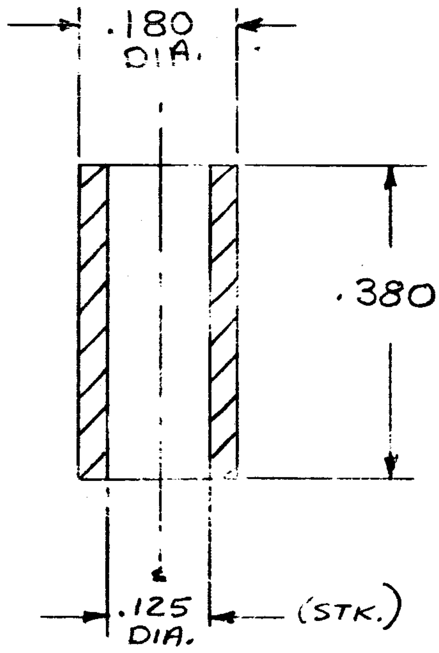
DRAWN	CHECKED	ENGINEER
MN 8/17/65	R.O.S. 8/18/65	P Br—

TITLE:
NUT

MAT'L	REQ	SCALE: 5×1	FINISH: 63RMS
S.S.	18	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-019		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

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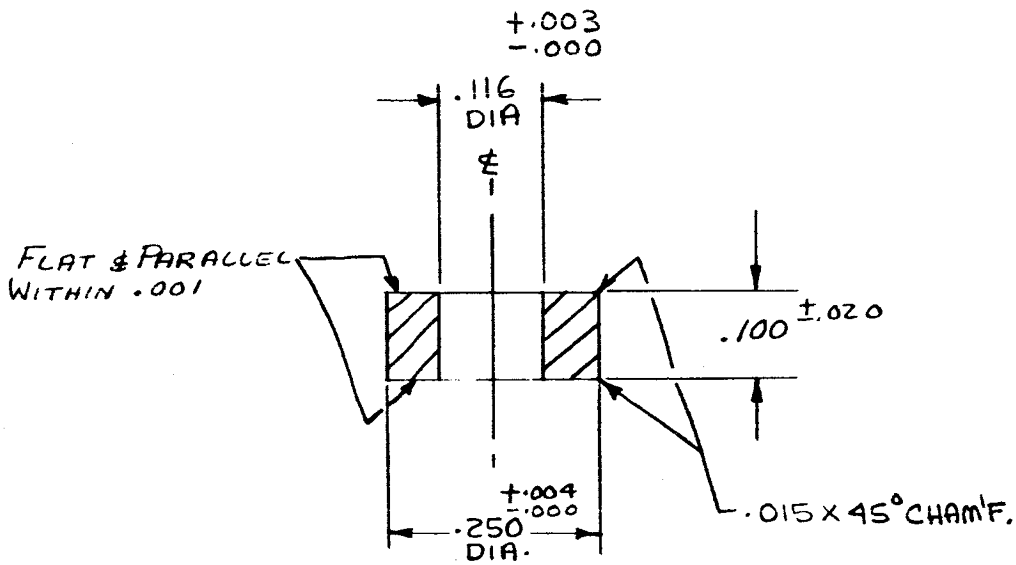
DRAWN	CHECKED	ENGINEER
MN 8/17/65	[illegible]	P. Brown

TITLE: Stud Insulator

MAT'L	REQ	SCALE: 5 x 1	FINISH: —
Al_2O_3	18	—	— 479-58
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-020		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .002 T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 x 1	FINISH: --
--	479-36
NEXT ASSY.	SIMILAR TO

MAT'L	REQ
Al_2O_3	18

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DRAWN	CHECKED	ENGINEER
MN 8/17/65	[illegible] 8/23/65	P Brown

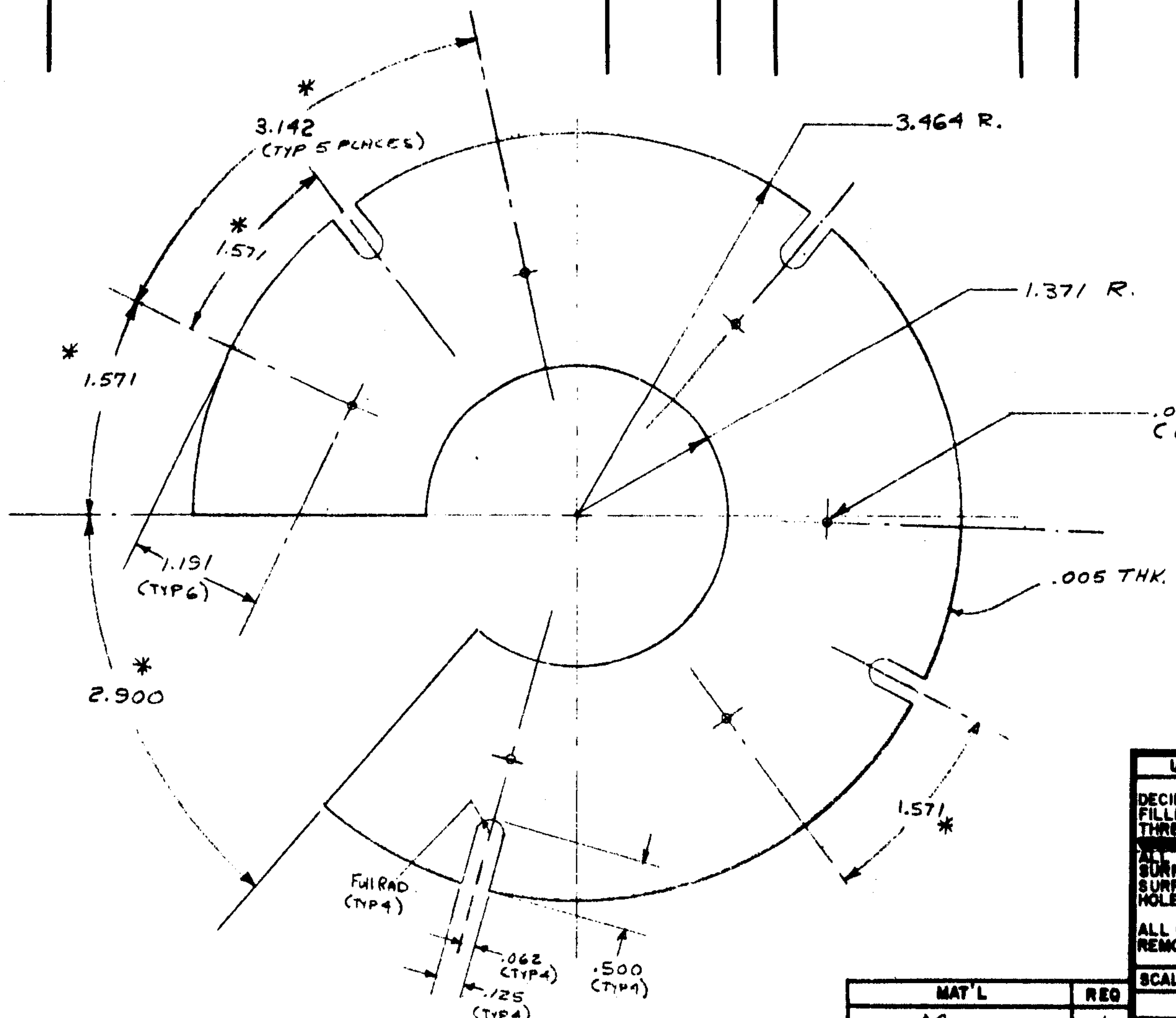
TITLE:

WASHER

SIZE	DRAWING NUMBER	SHEET	REV
A	550-021		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



1. TOLERANCES NOT TO BE CUMULATIVE.
2. DIMENSIONS WITH (*) ARE TO BE TAKEN FROM OUTER CIRCUMFERENCE

UNLESS OTHERWISE SPECIFIED
DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP. WITHIN .005 T.I.R.
SURFACES TO BE PAR. WITHIN .005 T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Mo	1

SCALE: FULL	FINISH:
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

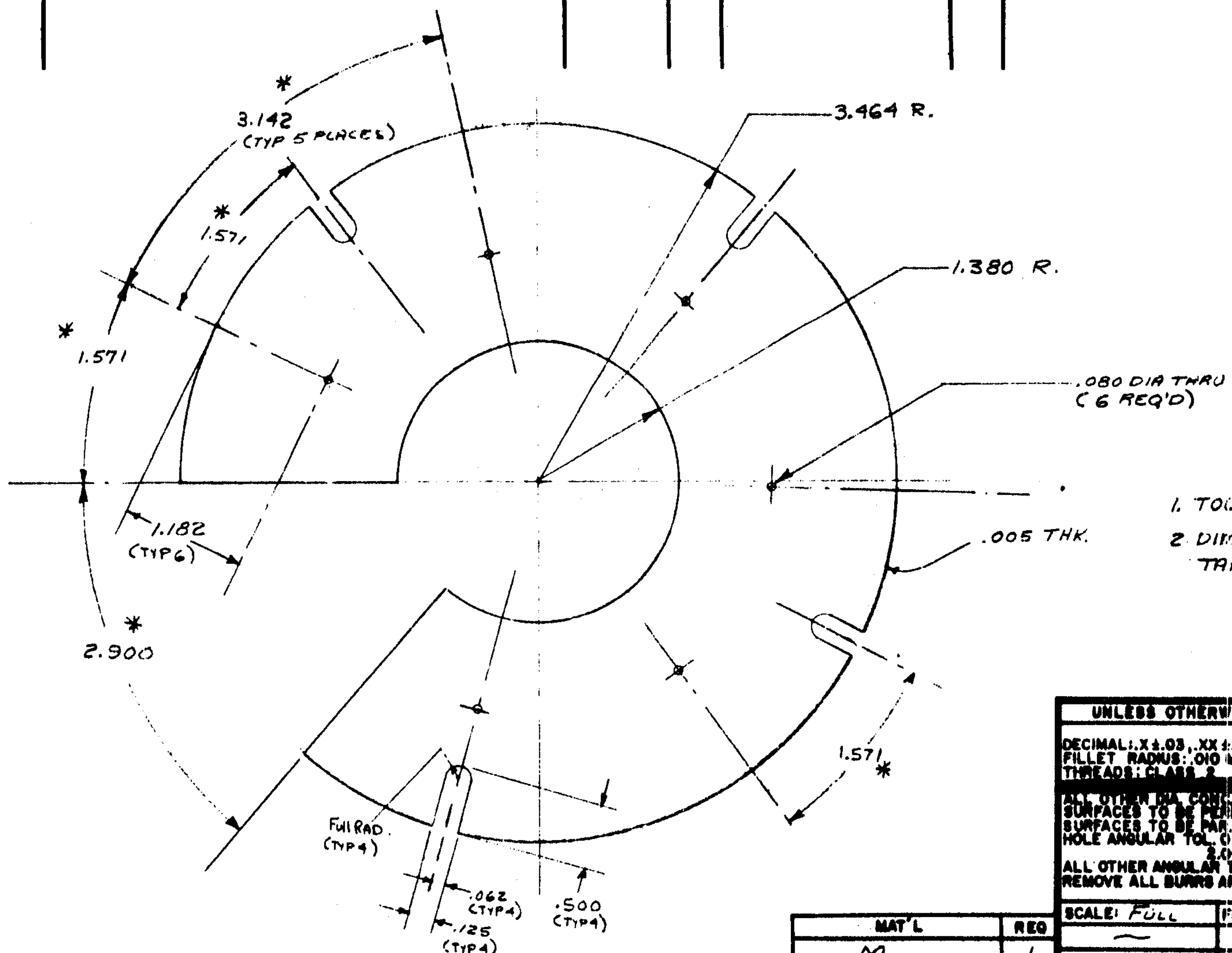
DRAWN	CHECKED	ENGINEER
MN 8/11/65	[illegible]	[illegible]

TITLE:
CONE SHIELD
#2

SIZE	DRAWING NUMBER	SHEET	REV
B	550-022		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



1. TOLERANCE NOT TO BE CUMULATIVE.
2. DIMENSIONS WITH (*) ARE TO BE TAKEN FROM OUTER CIRCUMFERENCE

MAT'L	REQ
Mo	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2 [redacted]
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP. WITHIN .005 T.I.R.
SURFACES TO BE PAR. WITHIN .005 T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD ±0° 5'
2.0-4.0 RAD ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: FULL	FINISH:
—	—
NEXT ASSY.	SIMILAR TO

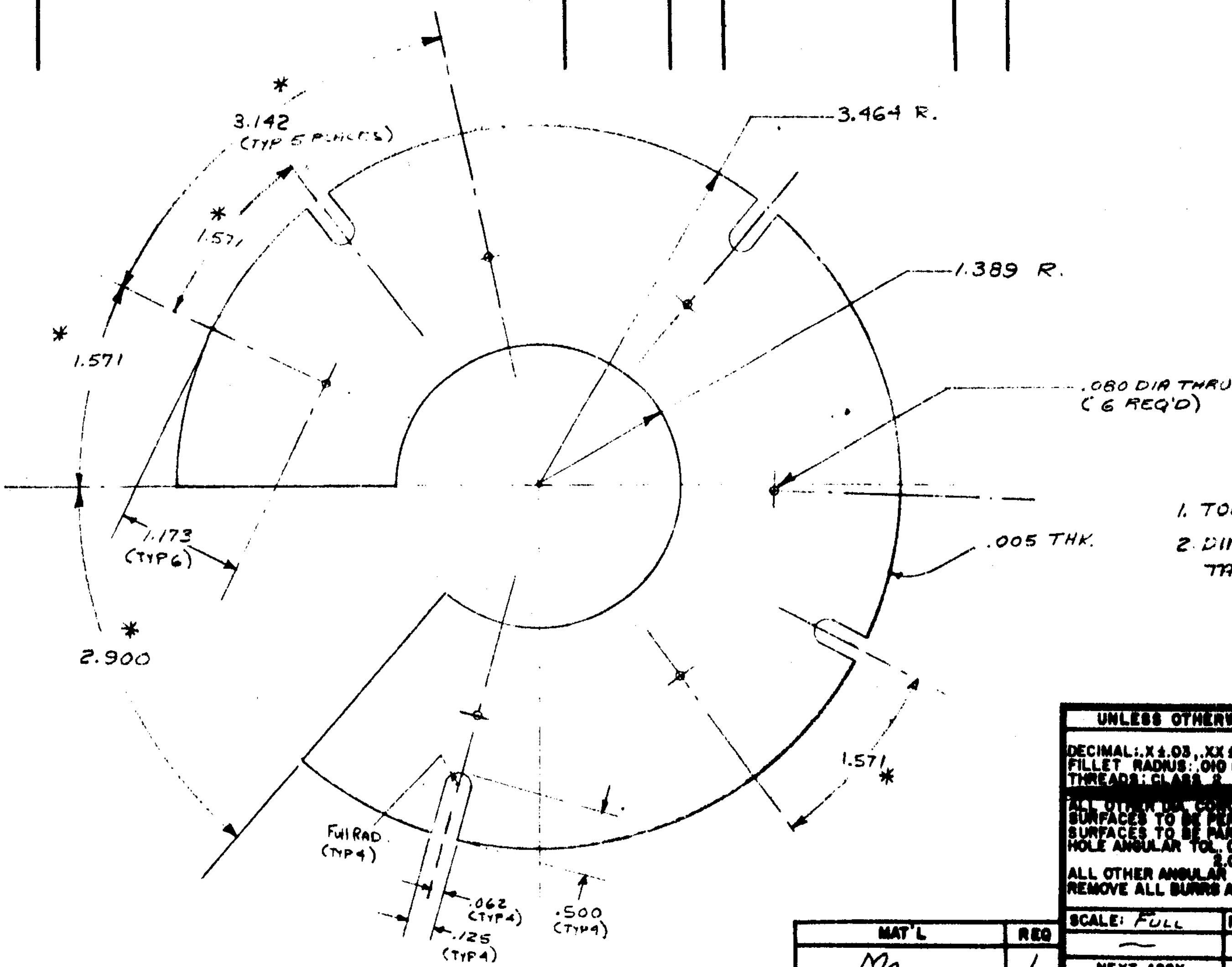
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE - WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/11/65	RGS. 8/19/65	P. Brown

TITLE: CONE SHIELD #3

SIZE	DRAWING NUMBER	SHEET	REV
B	550-023		

HOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR



1. TOLERANCES NOT TO BE CUMULATIVE.
2. DIMENSIONS WITH (*) ARE TO BE TAKEN FROM OUTER CIRCUMFERENCE

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP. WITHIN .005 T.I.R.
SURFACES TO BE PAR. WITHIN .005 T.I.R.
HOLE ANGULAR TOL. 0-1.0 RAD ±0°5'
2.0-1.0 RAD ±0°5'
ALL OTHER ANGULAR TOL. TO BE ±0°30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Mo	1

SCALE: FULL	FINISH
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

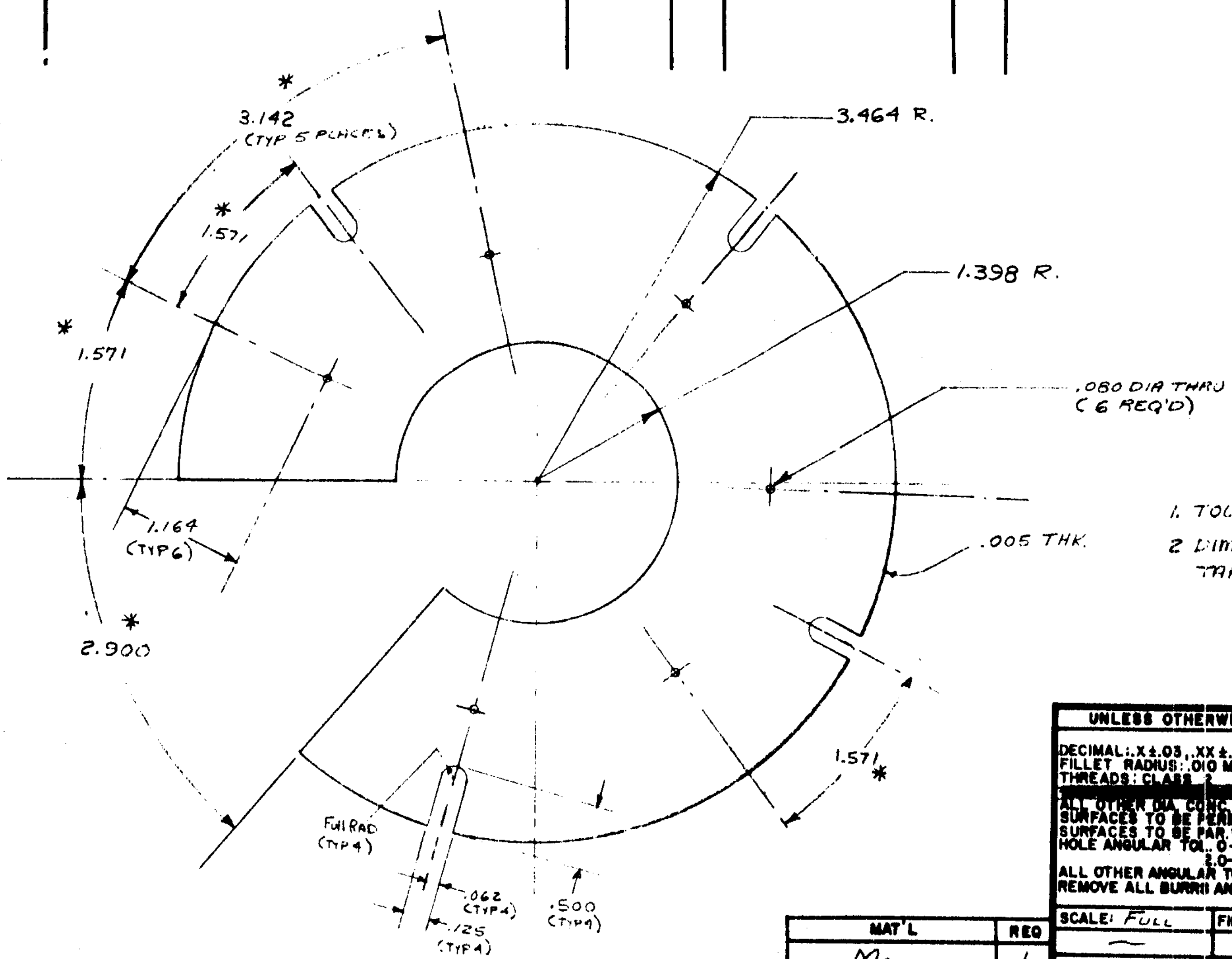
DRAWN	CHECKED	ENGINEER
MN 8/11/65	RJS 8/19/65	P. Br—

TITLE: CONE SHIELD #4

SIZE	DRAWING NUMBER	SHEET	REV
B	550-024		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



1. TOLERANCES NOT TO BE CUMULATIVE.
2. DIMENSIONS WITH (*) ARE TO BE TAKEN FROM OUTER CIRCUMFERENCE

MAT'L	REQ
Mo	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
ALL OTHER DIA. CONC WITHIN .005 — TIR
SURFACES TO BE PERP WITHIN .005 — TIR
SURFACES TO BE PAR. WITHIN .005 — TIR
HOLE ANGULAR TOL. 0-2.0 RAD ± 0° 5'
2.0-4.0 RAD ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: FULL	FINISH:
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

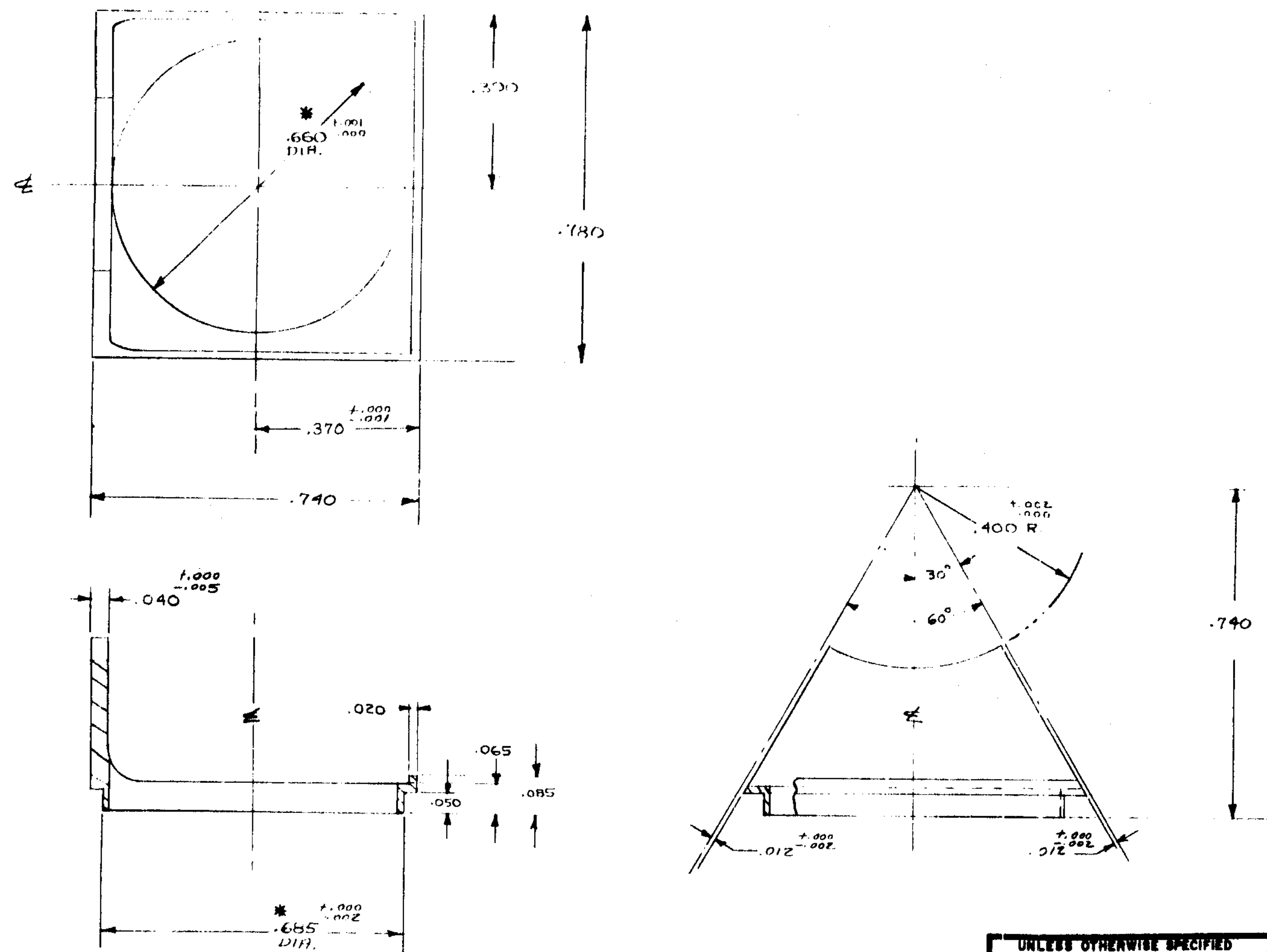
DRAWN	CHECKED	ENGINEER
MN 8/11/65	[illegible]	[illegible]

TITLE: CONE SHIELD #5

SIZE	DRAWING NUMBER	SHEET	REV
B	550-025		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN .002 T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 T.I.R.
SURFACES TO BE PERP. WITHIN .005 T.I.R.
SURFACES TO BE PAR. WITHIN .005 T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

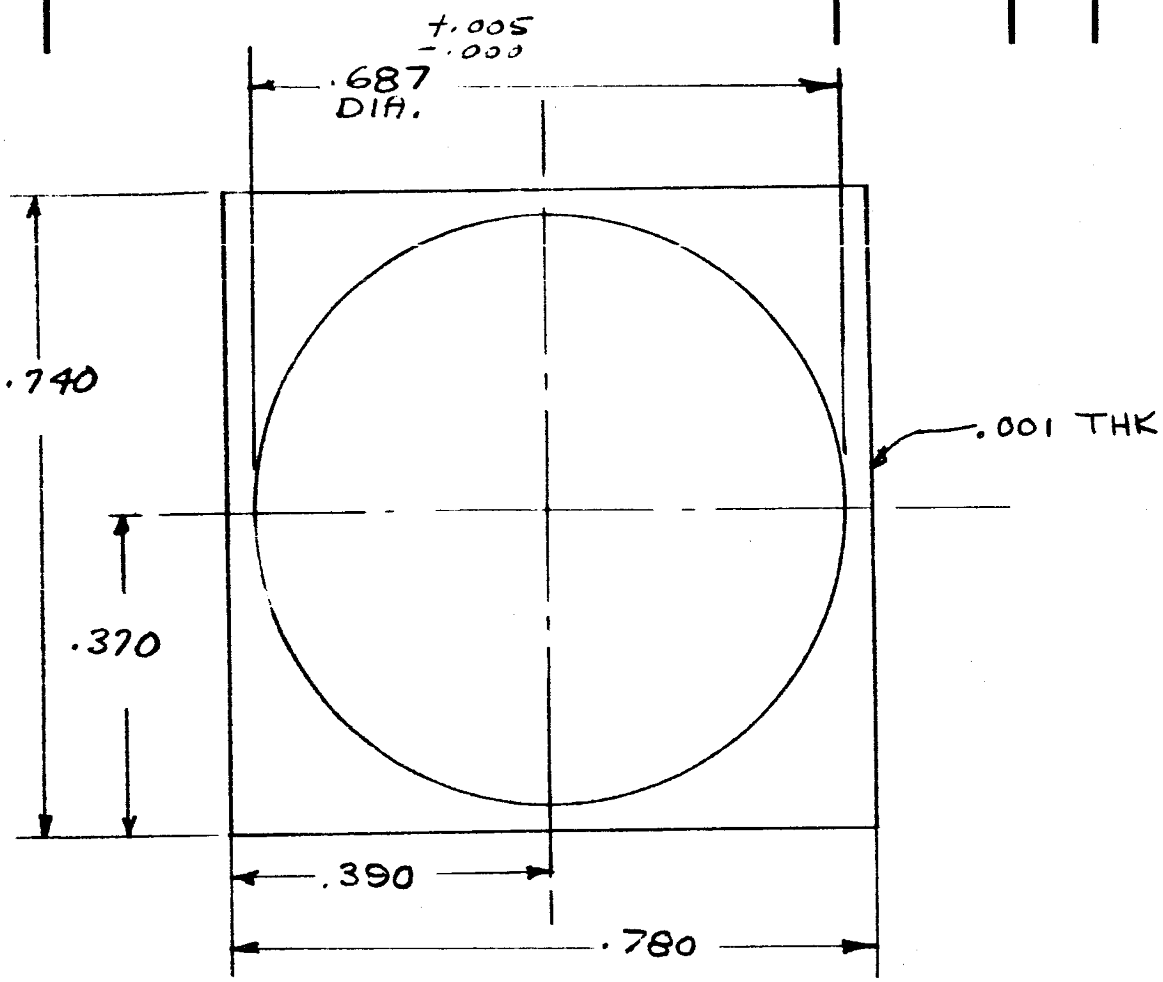
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM MASS 02154

DRAWN	CHECKED	ENGINEER
MN 9/4/6		

TITLE: Shoe Piece

MAT'L	REQ	SCALE: 5 X 1	FINISH: 63 RMS	SIZE	DRAWING NUMBER	SHEET	REV
Ta	1	NEXT ASSY.	SIMILAR TO	C	550-201		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/4/65	RBS 8/7/65	P. Brosens

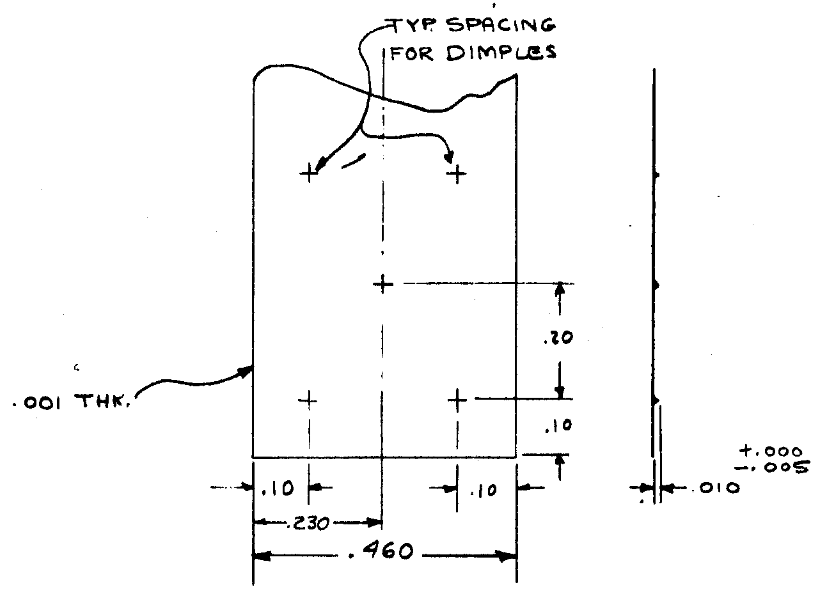
TITLE: Shoe Piece Shield

MAT'L	REQ	SCALE: 5 x 1	FINISH: ~
Ta	5	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-202		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



DEVELOPED LENGTH = 9.0 APPROX.

MAT'L	REQ
Ta	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
∗DIA.CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 x 1	FINISH: —
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
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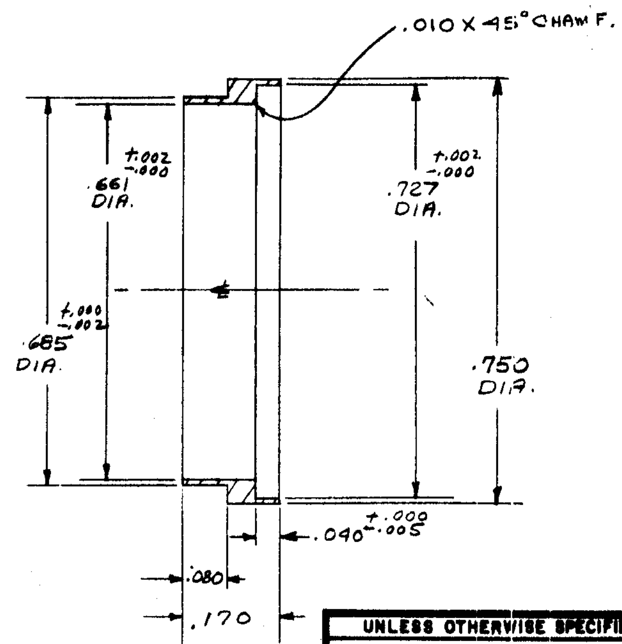
DRAWN	CHECKED	ENGINEER
MN 8/4/65	[illegible]	[illegible]

TITLE: CONVERTER SHIELD

SIZE	DRAWING NUMBER	SHEET	REV
B	550-203		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
Ta	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5X1	FINISH: 63 RMS
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM MASS 02154

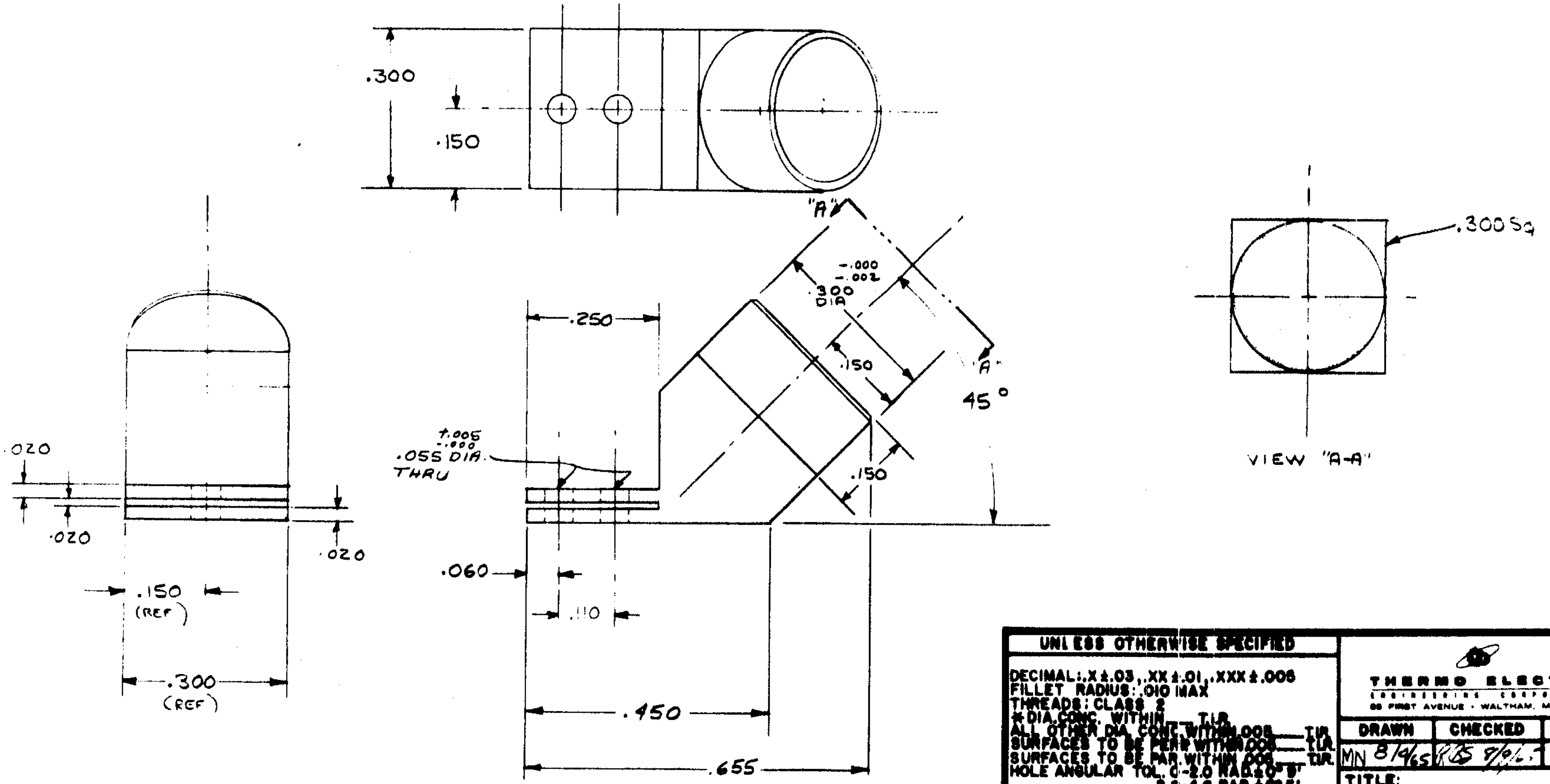
DRAWN	CHECKED	ENGINEER
MN 9/4/65	[illegible]	[illegible]

TITLE: SHIELD SUPPORT

SIZE	DRAWING NUMBER	SHEET	REV
B	550-204		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Nb	1

SCALE: 5x1	FINISH: 63 RMS
~	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

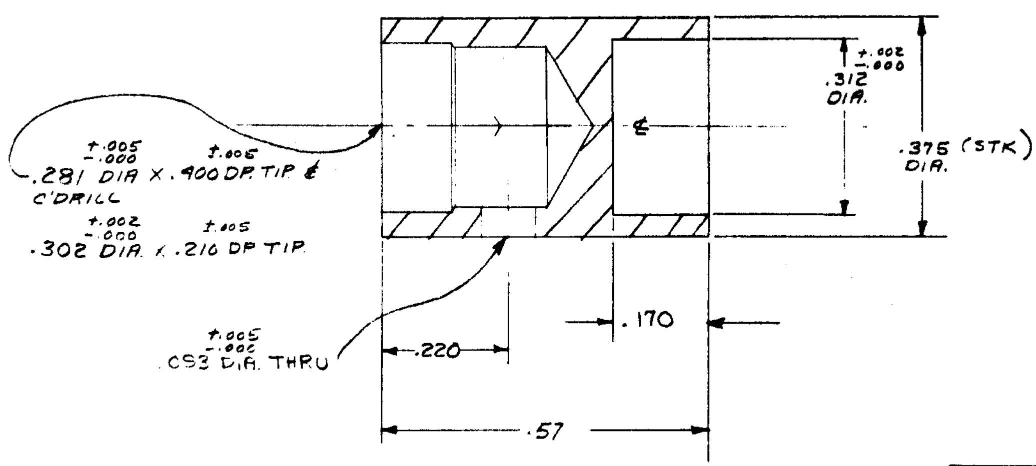
DRAWN	CHECKED	ENGINEER
MN 8/9/65	RCS 9/9/65	[illegible]

TITLE: LEAD CLAMP

SIZE	DRAWING NUMBER	SHEET	REV
B	550-207		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

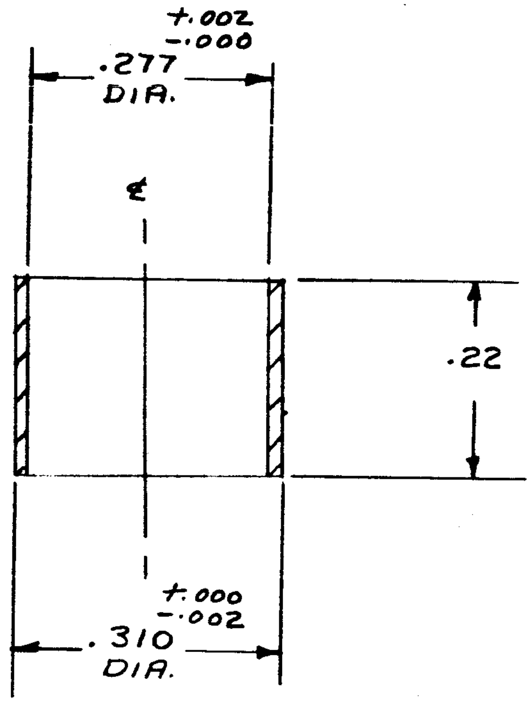
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65		

TITLE: LEAD ADAPTER

MAT'L	REQ	SCALE: 5 X	FINISH: 63 RMS	SIZE	DRAWING NUMBER	SHEET	REV
Cu	1	~	~	B	550-208		
		NEXT ASSY.	SIMILAR TO				

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

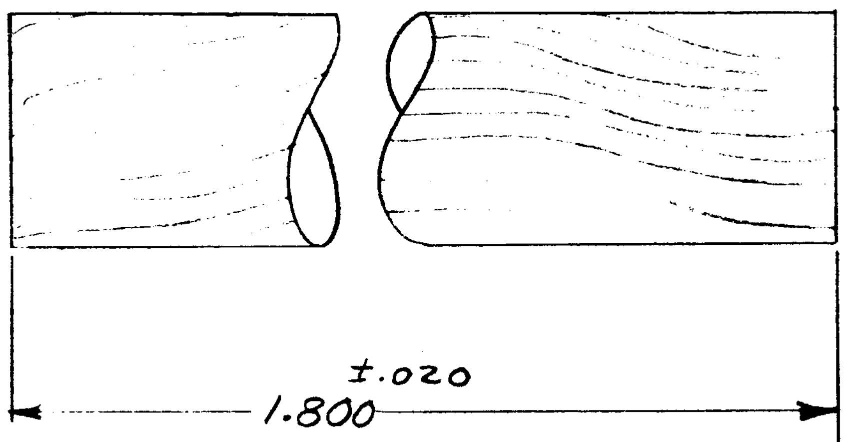
DRAWN	CHECKED	ENGINEER
MN 8/3/65	RBS 8/9/..	[illegible]

TITLE: LEAD SLEEVE

MAT'L	REQ	SCALE: 5x1	FINISH: 63RMS
Ni	2	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-209		

REV	DESCRIPTION	DATE	BY	APPR



MADE FROM:
#4 WELDING CABLE (PARANITE)

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65	RLS 8/4/65	PP ✓

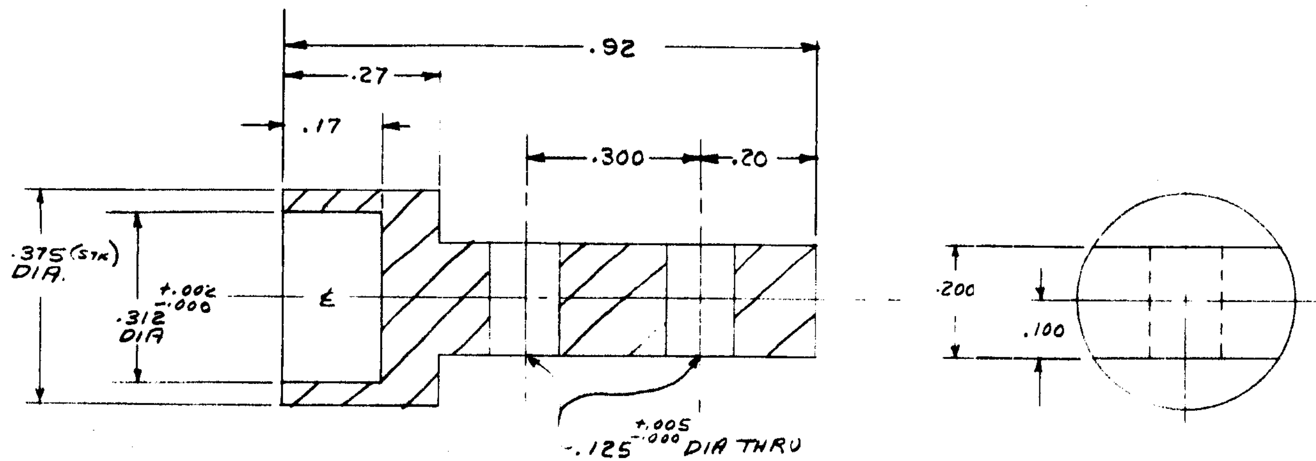
TITLE: LEAD

MAT'L	REQ	SCALE: 5X/	FINISH: —
Cu	1	—	—
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-210		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM MASS 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65		

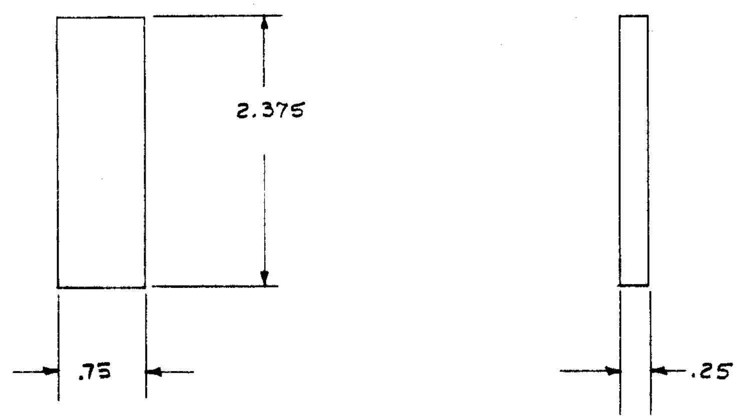
TITLE: LEAD TERMINAL

MAT'L	REQ	SCALE: 5X1	FINISH: 63 RMS
Cu	1	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
B	550-211		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
S. S.	4

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ____ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ____ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ____ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ____ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 8'
2.0-4.0 RAD. ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: FULL	FINISH: 63 RMS
~	~
NEXT ASSY.	SIMILAR TO

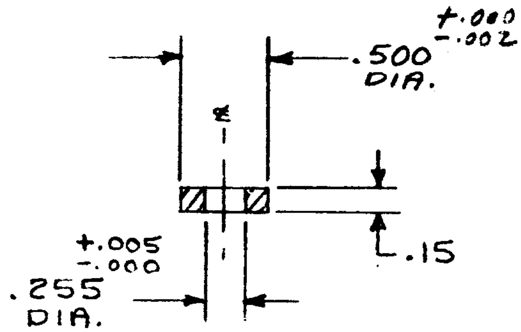
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65	RB 8/9/65	[illegible]

TITLE: WEB

SIZE	DRAWING NUMBER	SHEET	REV
B	550-302		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65	R.B.S. 8/9/65	[illegible]

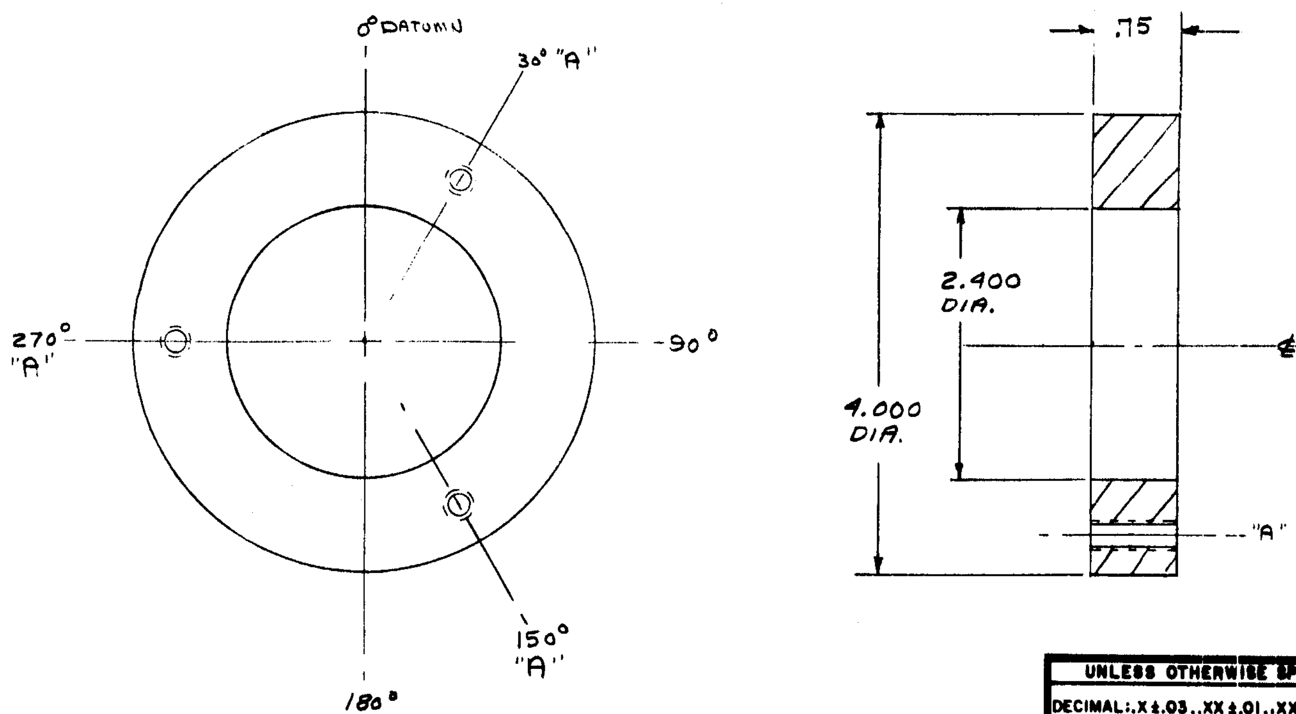
TITLE: INSULATOR

MAT'L	REQ	SCALE: Full	FINISH: ~
Al_2O_3	6	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	550-303		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"A"	1/4-20 TAP THRU	3.300	3

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 8'
2.0-4.0 RAD. ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ	SCALE: FULL	FINISH: 63RMS
		~	~
S.S.	1	NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

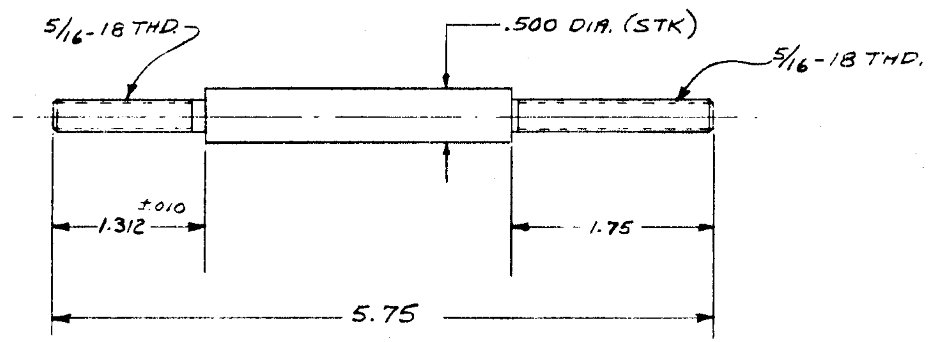
DRAWN	CHECKED	ENGINEER
MN 8/9/65	RBS	P Brown

TITLE: SUPPORT RING

SIZE	DRAWING NUMBER	SHEET	REV
B	550-305		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
S.S.	4

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: FULL	FINISH: ~
~	~
NEXT ASSY.	SIMILAR TO

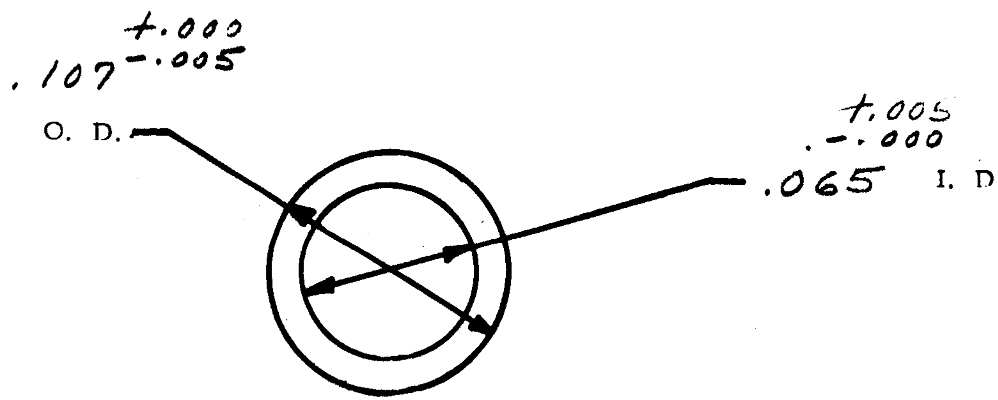
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

DRAWN	CHECKED	ENGINEER
[illegible]		

TITLE:
SUPPORT LEG

SIZE	DRAWING NUMBER	SHEET	REV
B	550-306		

REV	DESCRIPTION	DATE	BY	APPR



☑ BRAZE WASHER

USE .002..... THK. SHEET STOCK

☐ BRAZE RING

USE .... DIA. WIRE

			18	PB130
PART	SIZE	LOC	REQ	MAT'L

UNLESS OTHERWISE SPECIFIED

DEC. .X±1 .XX±.01 .XXX±.005

SCALE:

ANGLES ± 0°30' FINISH √ MAX

FILLET RAD .010 MAX
THREADS: CLASS 2
ALL DIAS. CONCENTRIC WITHIN .005 TIR
REMOVE ALL BURRS & SHARP EDGES

NEXT ASSY	SIM TO

NOTES

THERMO ELECTRON
ENGINEERING CORP.
WALTHAM 54, MASS.

DFT	MN	8-23-65	ENG	P. Brosn[illegible] 8-23-65
CHK	[illegible]	8/23/65	APP	

TITLE

SIZE	NUMBER	REV
A	550-2001	

Form 108

STANPAT CO. WHITESTONE, N.Y. U.S.A.

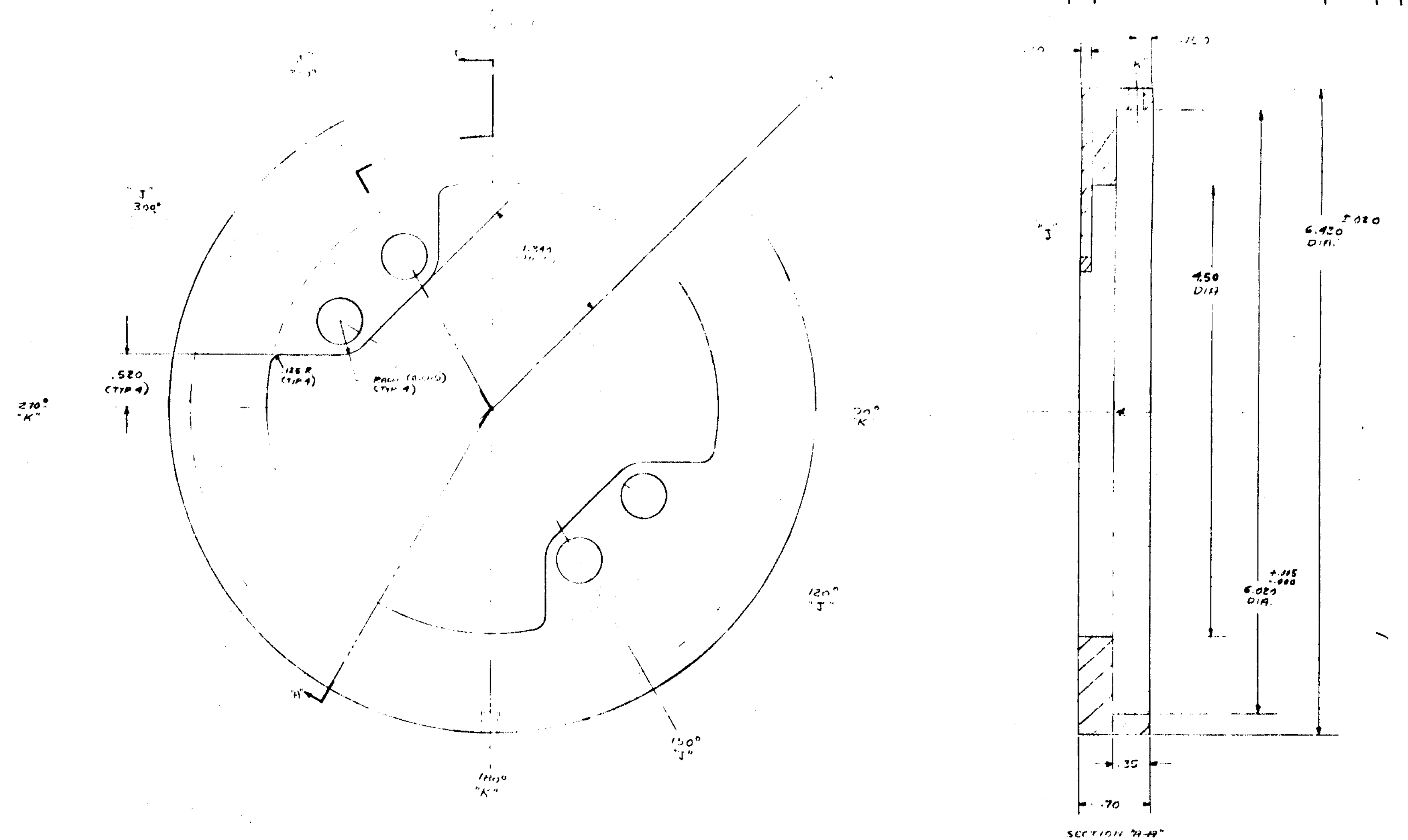
2.2 Detailed Mechanical Drawings for the Electron Bombardment Unit

549-001 to

549-2006

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"J"	.437 DIA. THRU	[illegible]	4
"K"	#8-32 TAP THRU	—	4

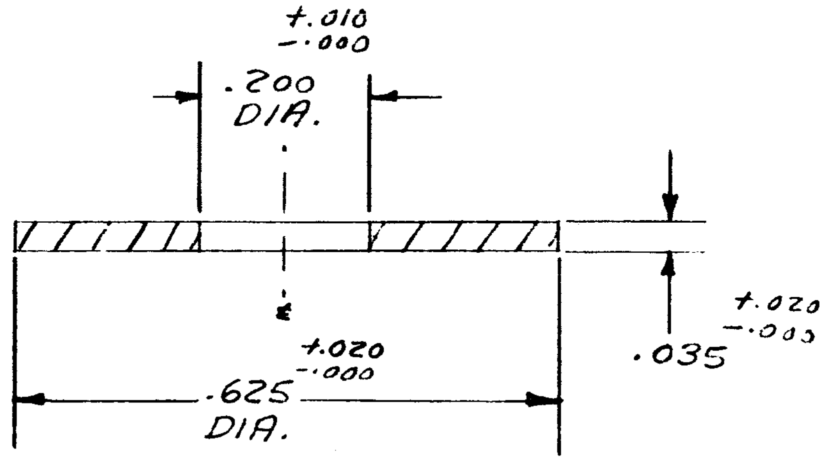
REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED	THERMO ELECTRON
DECIMAL ±.X±.03, .XX±.01, .XXX±.005	DRAWN / CHECKED / ENGINEER
ALL OTHER ANGULAR TOL.	TITLE: MAIN SUPPORT RING
REMOVE ALL BURRS AND EDGES	

MAT'L	REQ	SCALE: 2X1	FINISH	SIZE	DRAWING NUMBER
S.S.	1	NEXT ASSY: —	SIMILAR TO: —	D	[illegible]13 001

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA.CONC. WITHIN____ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005____ T.I.R.
SURFACES TO BE PERP. WITHIN .005____ T.I.R.
SURFACES TO BE PAR. WITHIN .005____ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

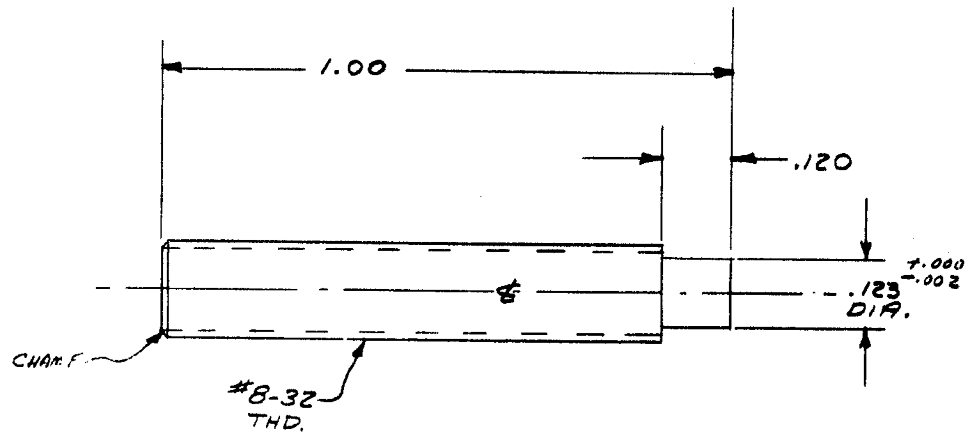
DRAWN	CHECKED	ENGINEER
MN 8/9/65	[illegible]	[illegible]

TITLE: WASHER

MAT'L	REQ	SCALE: 5X1	FINISH:	SIZE	DRAWING NUMBER	SHEET	REV
S.S.	4	~	~	A	549-002		
		NEXT ASSY.	SIMILAR TO				

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
S.S.	4

SCALE: 5x/	FINISH: 63RMS
—	—
NEXT ASSY.	SIMILAR TO

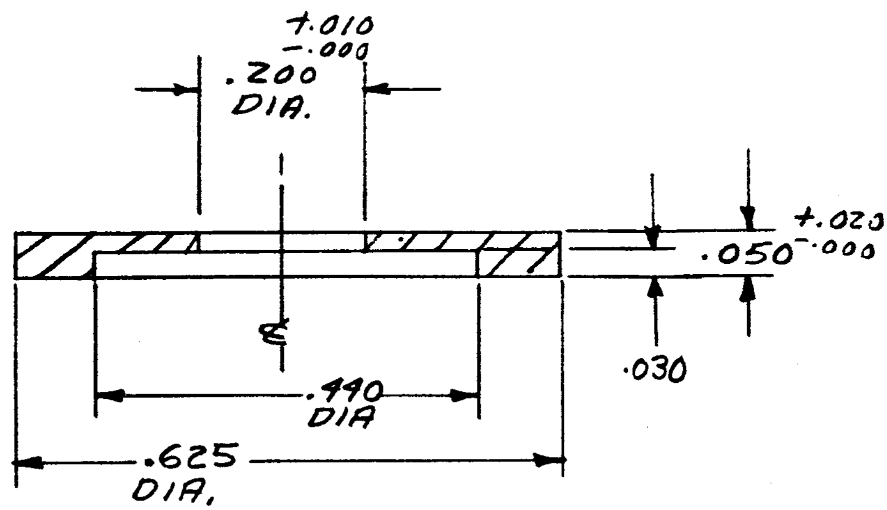
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/3/65	DS 8/19/65	D. Brown

TITLE: THREADED POST

SIZE	DRAWING NUMBER	SHEET	REV.
B	549.004		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA.CONC. WITHIN___ T.I.R.
ALL OTHER DIA. CONC.WITHIN.005___T.I.R.
SURFACES TO BE PERP. WITHIN .005___T.I.R.
SURFACES TO BE PAR. WITHIN .005___T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE • WALTHAM, MASS. 02154

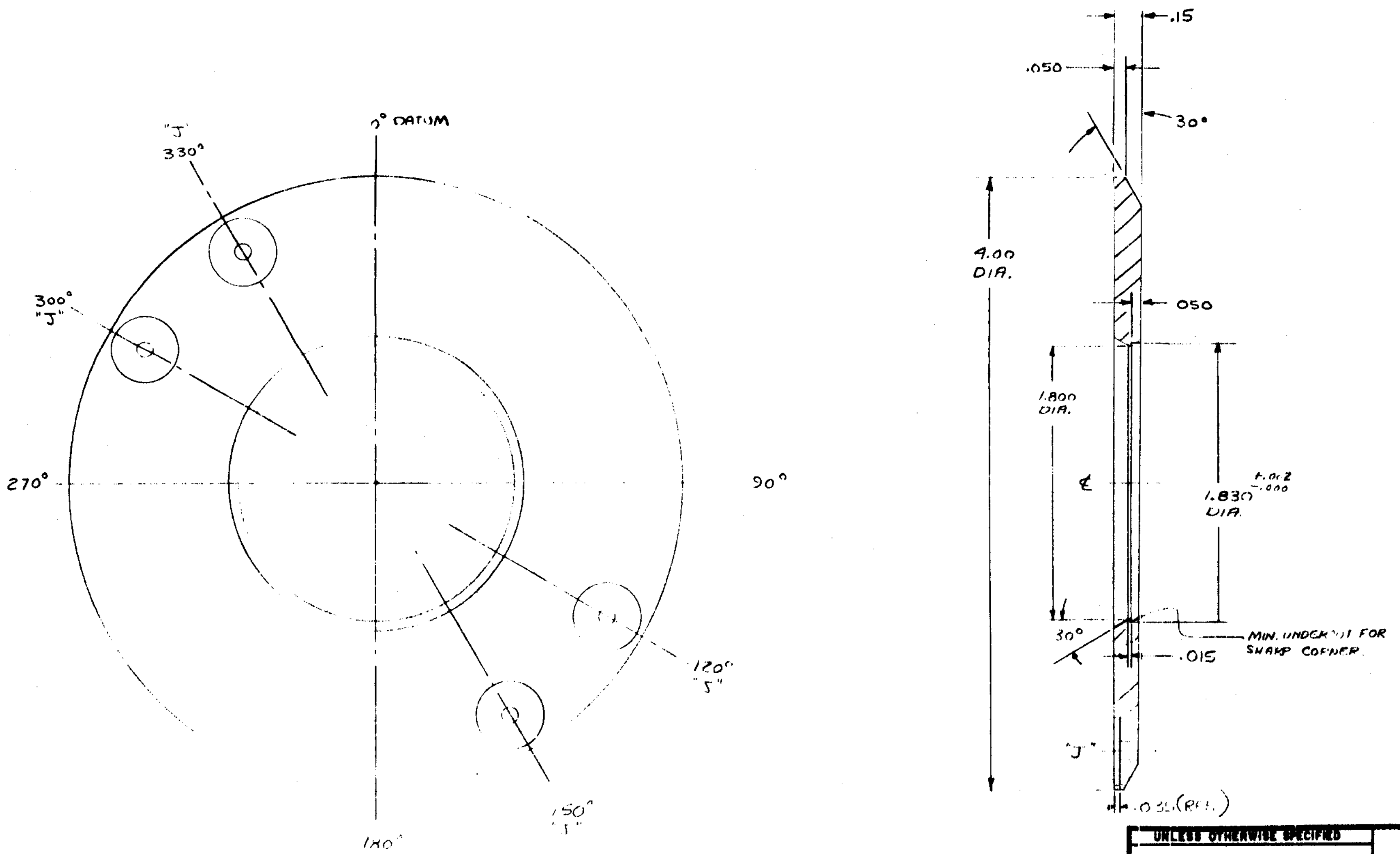
DRAWN	CHECKED	ENGINEER
MN 8/9/65	[illegible]	[illegible]

TITLE: SPRING RETAINER WASHER

MAT'L	REQ	SCALE: 5 X 1	FINISH:	SIZE	DRAWING NUMBER	SHEET	REV
S.S.	4	—	—	A	549-005		
		NEXT ASSY.	SIMILAR TO				

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"J"	.125 [illegible] THRU & COUNTERBORE .440 [illegible] X .035 DP.	3.500	4

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
⊕ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 5'
2.0-4.0 RAD. ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ	SCALE: 2/1	FINISH: [illegible]
[illegible]	1	NEXT ASSY.	SIMILAR TO

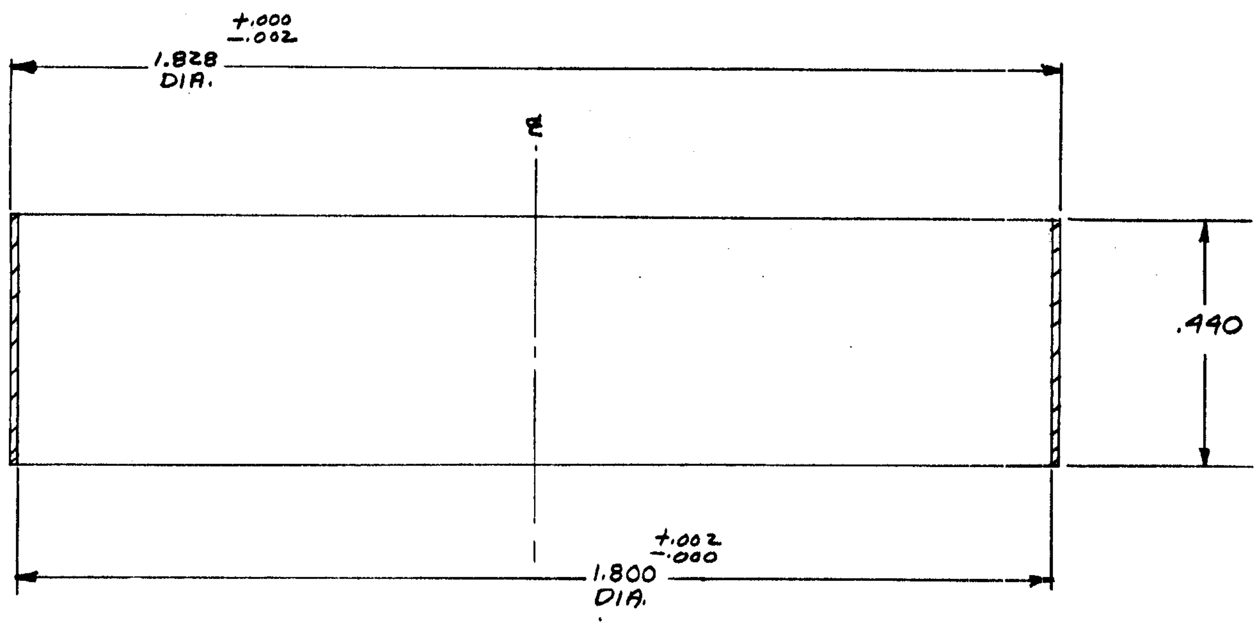
THERMO ELECTRON CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 9/4 [illegible]	[illegible] 3/96	

TITLE: Movable Support

SIZE	DRAWING NUMBER	SHEET	REV
C	[illegible] 007		

HOLE	DESCRIPTION	DBC	NO. OF HOLES	REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ	SCALE: 5X 1	FINISH: 63 RMS
DH 142	1	~	~
		NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

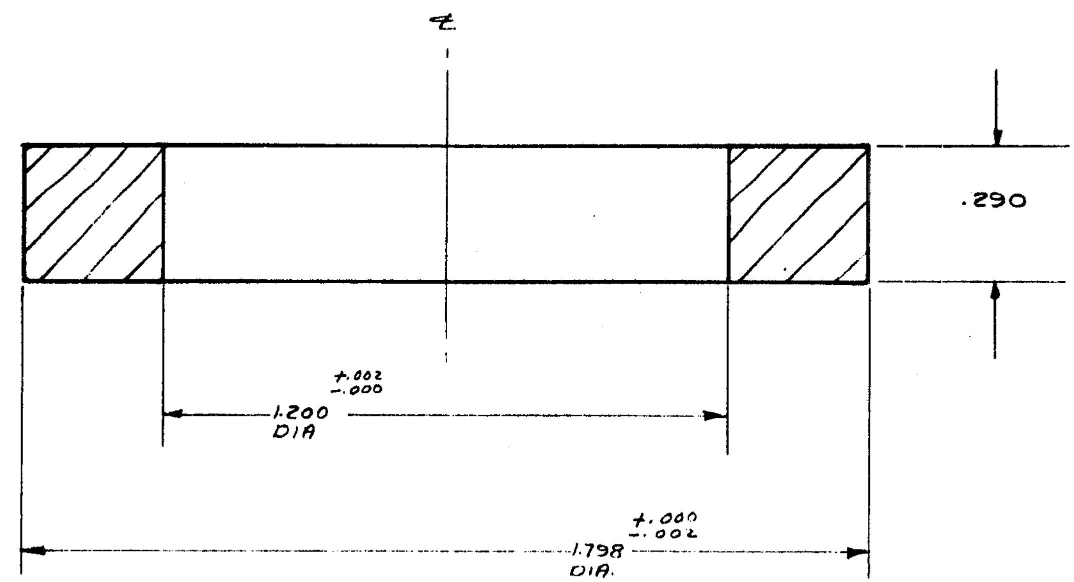
DRAWN	CHECKED	ENGINEER
MN 8/9/65	RGB 8/18/65	P.B.

TITLE: INSULATOR FLANGE (OUTER)

SIZE	DRAWING NUMBER	SHEET	REV
B	549-008		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
⌀ DIA CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 8'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Al_2O_3	1

SCALE: 5X1	FINISH: ~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM MASS 02154

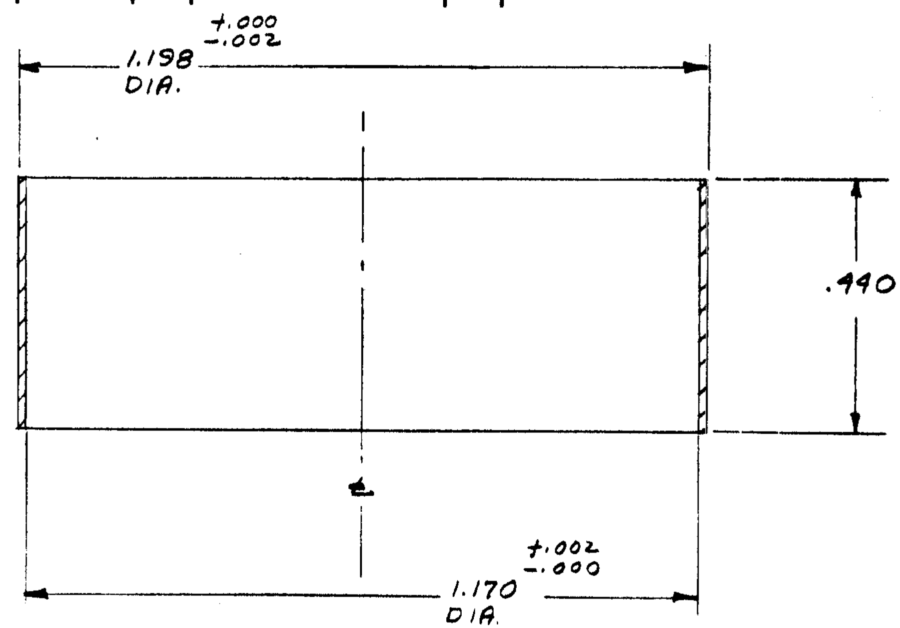
DRAWN	CHECKED	ENGINEER
MN 8/9/66	KB 8/9/66	DH

TITLE: HIGH VOLTAGE INSULATOR

SIZE	DRAWING NUMBER	SHEET	REV
C	549-009		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
DH 142	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 x 1	FINISH: 63 RMS
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

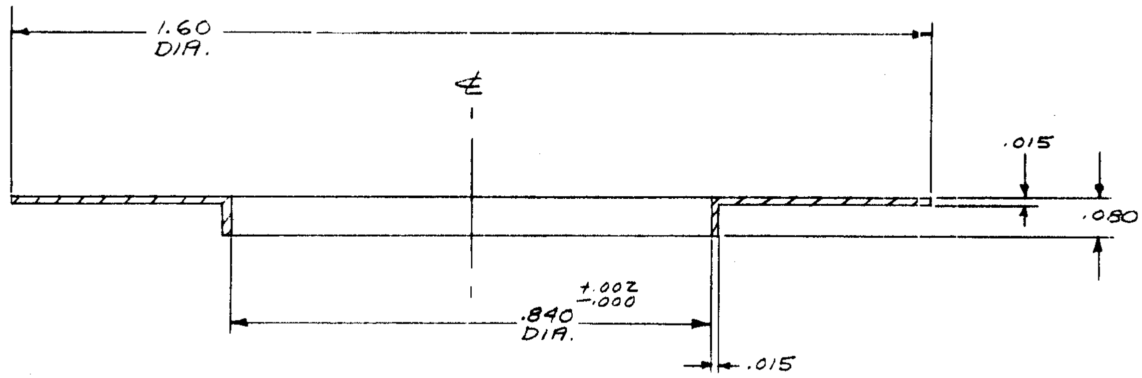
DRAWN	CHECKED	ENGINEER
MN 8/9/65	BS 8/19/65	[illegible]

TITLE: INSULATOR FLANGE (INNER)

SIZE	DRAWING NUMBER	SHEET	REV
B	549-010		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Ta	1

SCALE: 5X1	FINISH: 63 RMS
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

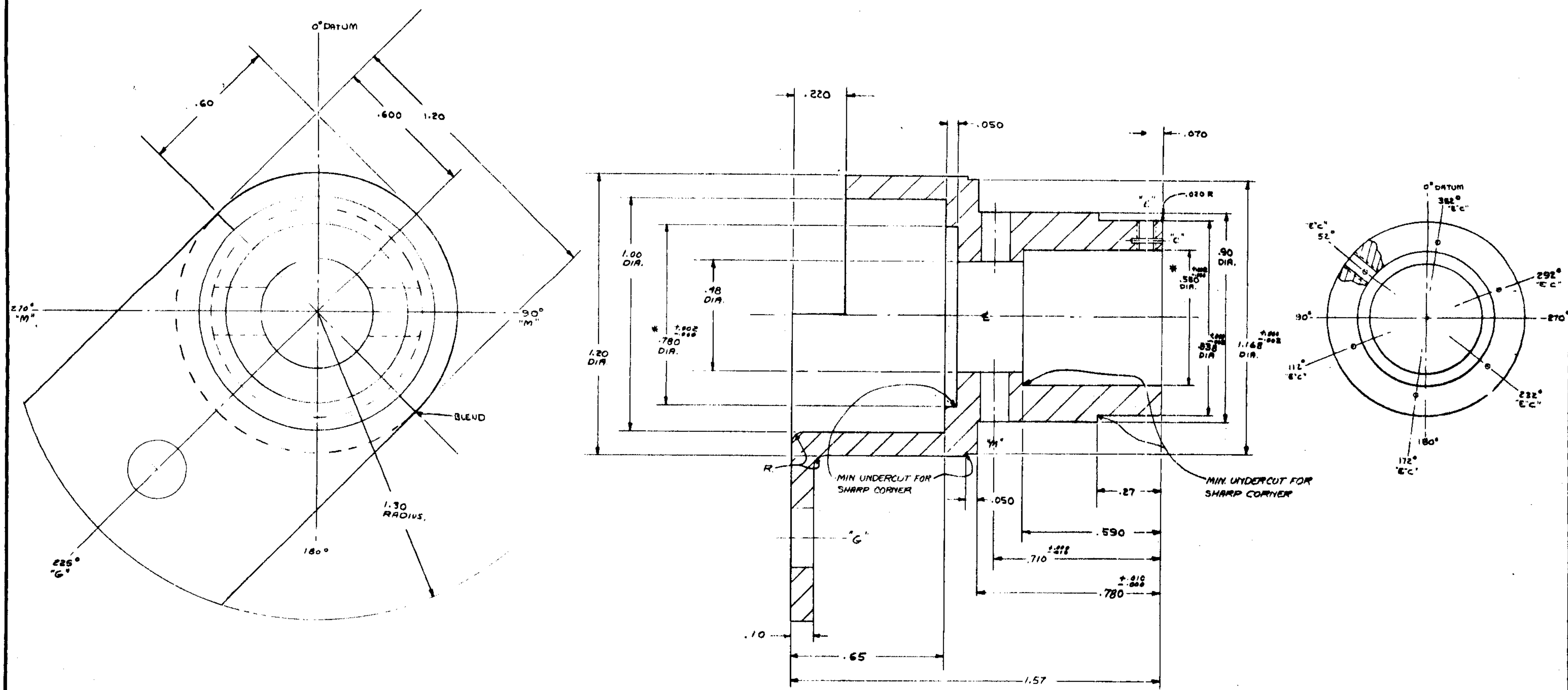
DRAWN	CHECKED	ENGINEER
MV 8/9/65	GS 8/19/65	

TITLE: METAL VAPOR SHIELD

SIZE	DRAWING NUMBER	SHEET	REV
B	549-011		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"C"	.035 $^{+.002}_{-.000}$ DIA. × .190 DP. TIP.	.660	6
"E"	#2-56 TAP THRU	~	6
"G"	.260 $^{+.002}_{-.000}$ DIA. THRU	1.900	1
"M"	.125 $^{+.010}_{-.000}$ DIA. HOLE THRU	~	2

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

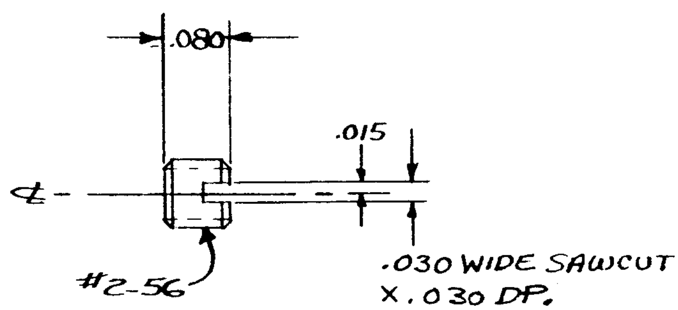
THERMO ELECTRON

TITLE: FILAMENT SUPPORT (OUTER)

MAT'L: Ta. | REQ: 1 | SCALE: 5×1 | FINISH: 63 RMS | NEXT ASSY. | SIMILAR TO

D 549-012

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
✱ DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/9/65	[illegible] 8/19/65	[illegible]

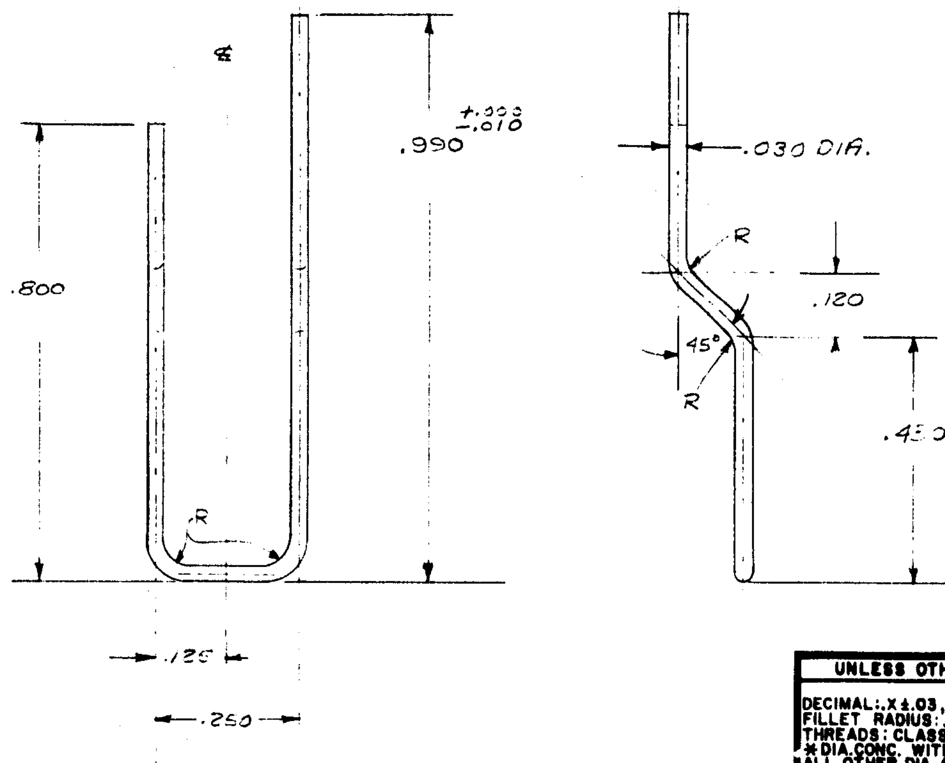
TITLE: Filament Set Screw

MAT'L	REQ	SCALE: 5×1	FINISH: ~
Ta-W	12	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	549-013		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
W	6

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
2.0-4.0 RAD. ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5 X 1	FINISH: —
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

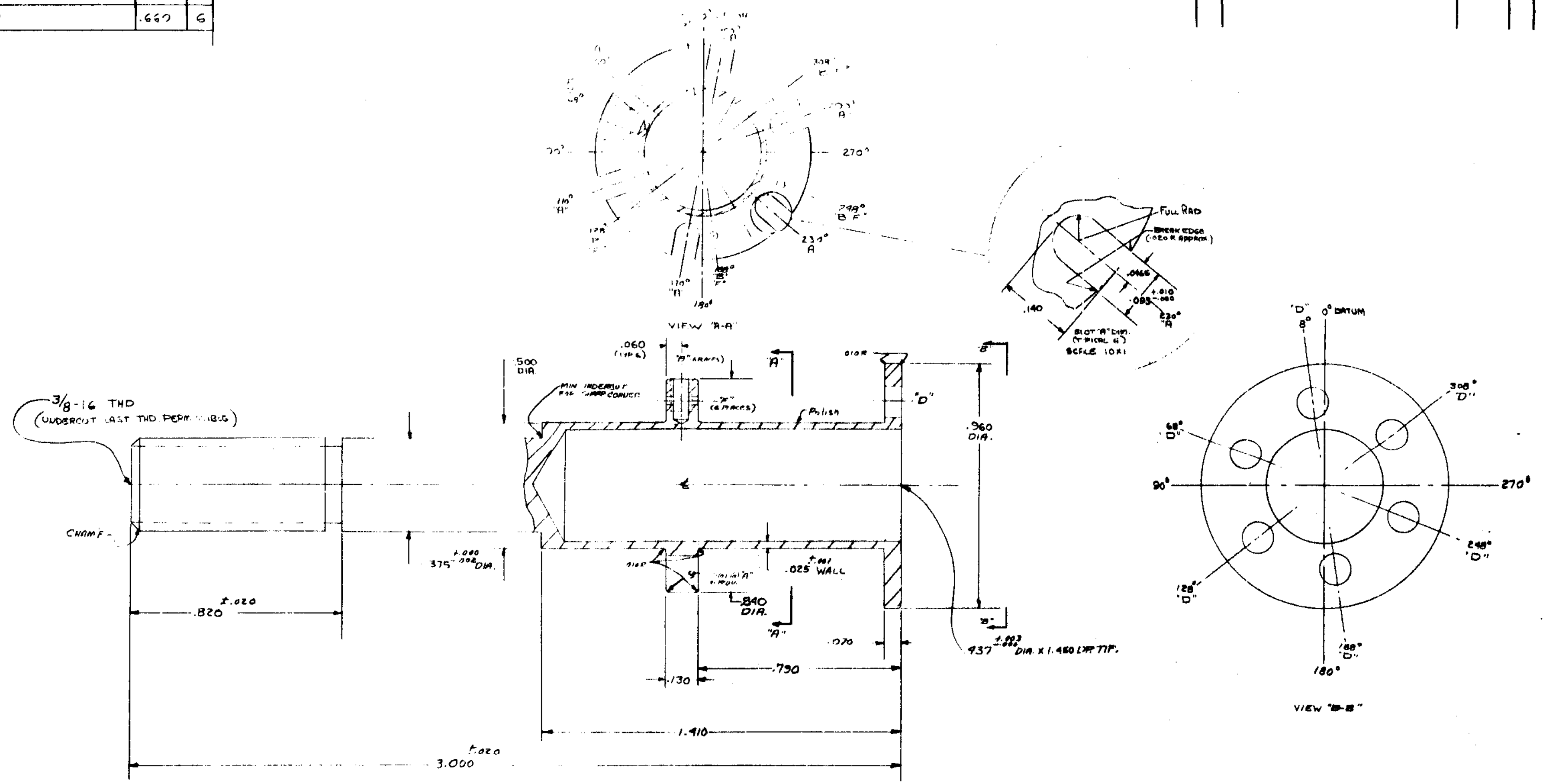
DRAWN	CHECKED	ENGINEER
MN 8/9/65	[illegible]	

TITLE: FILAMENT

SIZE	DRAWING NUMBER	SHEET	REV
B	540-214		

HOLE	DESCRIPTION	DBC	NO. OF HOLES
"B"	TAP DRILL .175 DP TIP MAX & #2-56 TAP x .130 DP MIN	—	6
"D"	.126 $^{\pm.005}$ DIA. THRU	.660	6
"F"	.035 $^{+.002}_{-.000}$ DIA. THRU	.660	6

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

MAT'L	REQ	SCALE	FINISH		
Ta	1	5 X 1	63 RMS		
		NEXT ASSY.	SIMILAR TO		

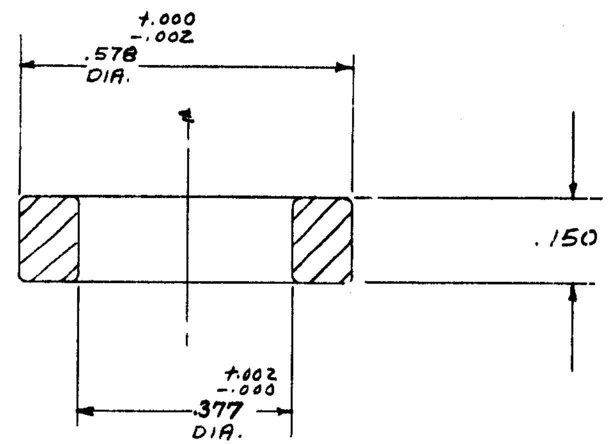
THERMO ELECTRON

TITLE: FILAMENT SUPPORT (CENTRAL)

D 549-016

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
Al_2O_3	1

SCALE: 5X1	FINISH: —
—	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

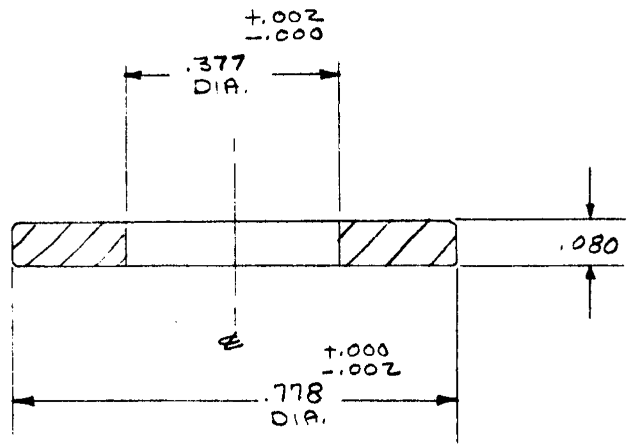
DRAWN	CHECKED	ENGINEER
MN 8/9/65	JBS 8/9/65	[illegible]

TITLE:
LOW VOLTAGE
INSULATOR

SIZE	DRAWING NUMBER	SHEET	REV
B	549-017		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
Al_2O_3	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
*DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5x1 | FINISH: —

NEXT ASSY.	SIMILAR TO
—	—

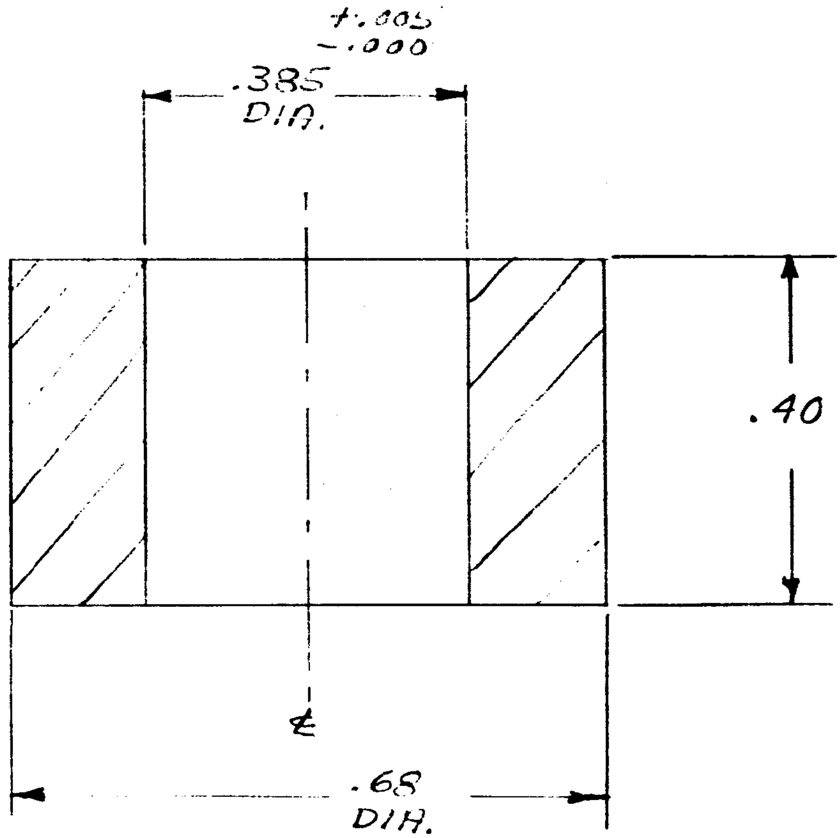
THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 8/9/65	8/10/65	

TITLE: INSULATING WASHER

SIZE	DRAWING NUMBER	SHEET	REV
B	549-018		

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN		

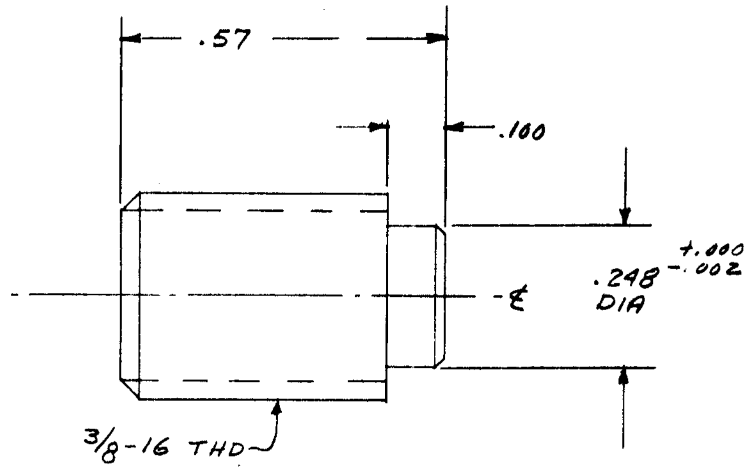
TITLE: WASHER LOCATING

MAT'L	REQ	SCALE:	FINISH:
	1	NEXT ASSY	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
A	549-019		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
Ta	1

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 8'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5x1	FINISH: 63RMS
~	—
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

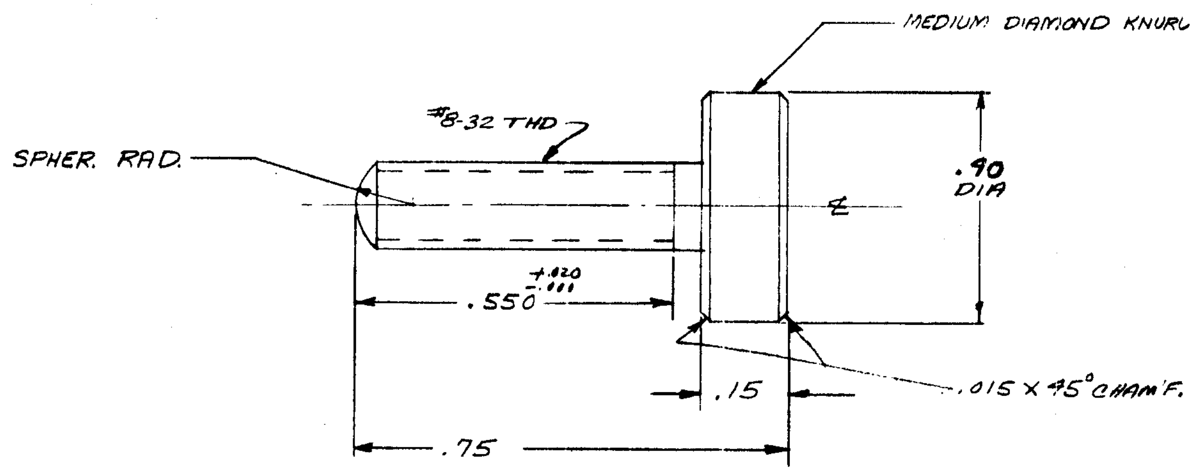
DRAWN	CHECKED	ENGINEER
MN 8/9/65	KS 8/19/65	[illegible]

TITLE: TERMINAL STUD

SIZE	DRAWING NUMBER	SHEET	REV
B	549-021		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ± 0° 9'
2.0-4.0 RAD. ± 0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

MAT'L	REQ
S.S.	4

SCALE: 5 X 1	FINISH: —
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

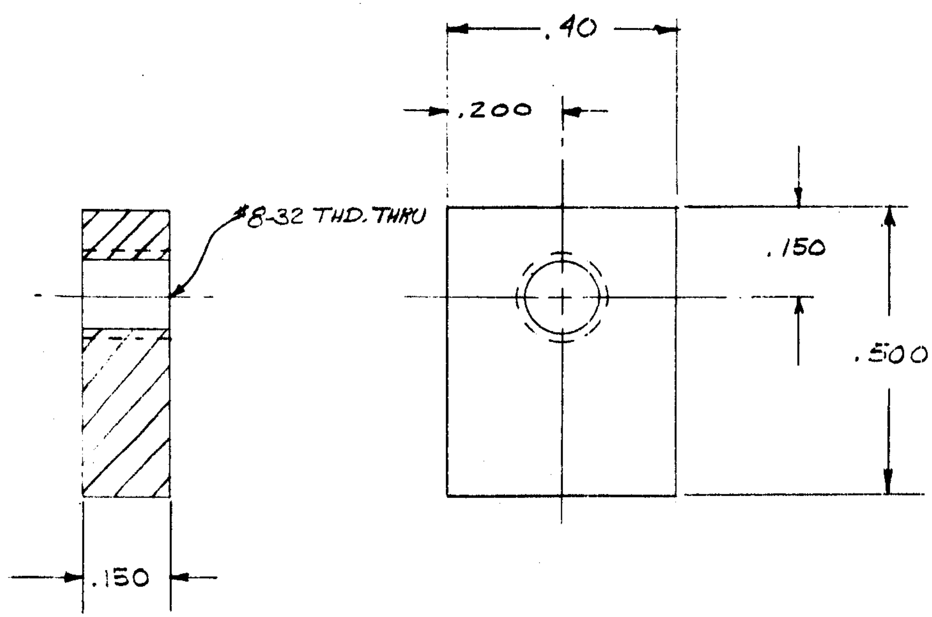
DRAWN	CHECKED	ENGINEER
MN 8/9/65	RUS 8/10/65	[illegible]

TITLE: TRAVERSE ADJUST SCREW

SIZE	DRAWING NUMBER	SHEET	REV
B	549-022		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



MAT'L	REQ
S.S.	4

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 5'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

SCALE: 5X1	FINISH: 63RMS
~	~
NEXT ASSY.	SIMILAR TO

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS 02154

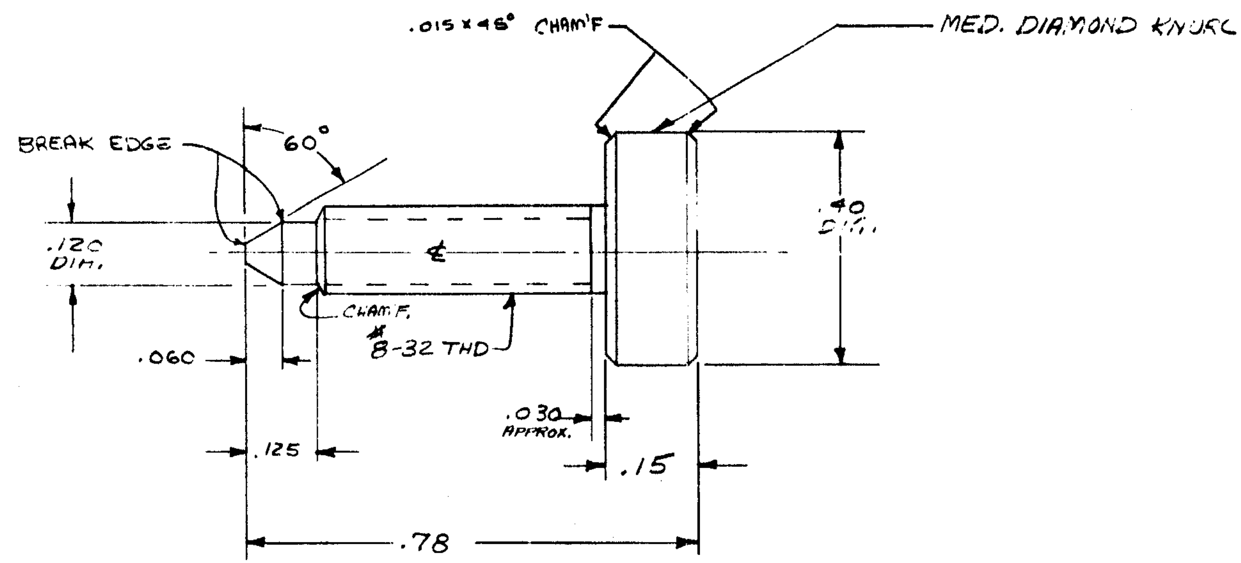
DRAWN	CHECKED	ENGINEER
MN 8/9/	RAS 8 9/	

TITLE:
SUPPORT (ADJUSTMENT SCREW)

SIZE	DRAWING NUMBER	SHEET	REV
B	549-023		

HOLE	DESCRIPTION	DBC	NO. OF HOLES

REV	DESCRIPTION	DATE	BY	APPR



UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ± .03, .XX ± .01, .XXX ± .005
FILLET RADIUS: .010 MAX
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0-2.0 RAD. ±0° 9'
2.0-4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ± 0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON
ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

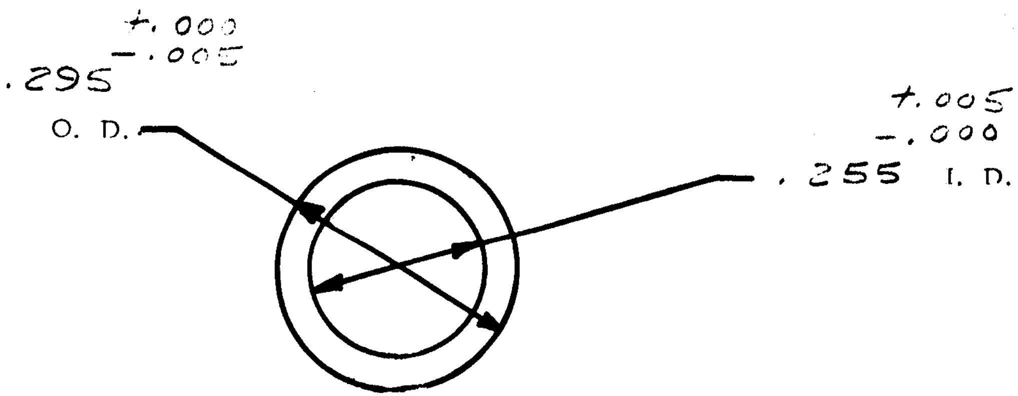
DRAWN	CHECKED	ENGINEER
MN 8/9/65	RBS 8/19/65	

TITLE: Clamp Thumb Screw

MAT'L	REQ	SCALE: 5X1	FINISH: ~
S.S.	4	~	~
		NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
B	549-024		

REV	DESCRIPTION	DATE	BY	APPR



☑ BRAZE WASHER

USE .003..... THK. SHEET STOCK

☐ BRAZE RING

USE .... DIA. WIRE

			1	FE75	
PART	SIZE	LOC	REQ	MAT'L	NOTES

UNLESS OTHERWISE SPECIFIED

DEC. .X±1 .XX±.01 .XXX±.005

SCALE: NONE

ANGLES ± 0°30' FINISH √ MAX

FILLET RAD .010 MAX
THREADS: CLASS 2
ALL DIAS. CONCENTRIC WITHIN .005 TIR
REMOVE ALL BURRS & SHARP EDGES

NEXT ASSY	SIM TO

THERMO ELECTRON
ENGINEERING CORP.
WALTHAM 54, MASS.

DR	MN	8/9/65	ENG	[illegible]	8-20-65
CHK	KCS	8/19/65	APP		

TITLE: WASHER

SIZE	NUMBER	REV
A	549-2006	

Form 108

STANPAT CO WHITESTONE, N.Y. U.S.A.

3.0 Assembly Data for Generator and Electron Bombardment Unit

3.1 List of Suggested Materials Vendors

Tantalum:	Kawecki Chemical 220 East 42nd Street New York, New York
Tungsten:	Universal Cyclops Steel Drawer 153 Bridgeville, Pennsylvania
	Kawecki Chemical 220 East 42nd Street New York, New York
Driver Harris 142:	Driver Harris 202 Middlesex Street Harrison, New Jersey
O.F.H.C. Copper:	Utility Brass & Copper 116 King Street Brooklyn, New York
Molybdenum:	Universal Cyclops Steel Drawer 153 Bridgeville, Pennsylvania
	Climax Molybdenum of Michigan 2170 Avenue of the Americas New York, 20, New York
Niobium:	Kawecki Chemical 220 East 42nd Street New York, New York
	National Research Corporation Metals Division 45 Industrial Place Newton, Massachusetts

PROPRIETARY

Nickel:	The International Nickel Co., Inc. Huntington 17, W. Virginia
Aluminum Oxide:	McDaniel Refractory (material only) Post Office Box 560 Beaver Falls, Pennsylvania
	Technical Ceramics (machinery only) 65 Walnut Street Peabody, Massachusetts
	Western Gold & Platinum 525 Harbor Boulevard (machine & material) Belmont, California
	Raytheon Company (metallizing) Micro Wave & Power Tube Division Foundry Avenue Waltham, Mass.
Stainless Steel:	Industrial Stainless Steels, Inc. Subsidiary of Eastern Stainless Steel Corp. 255 Bent Street Cambridge 41, Massachusetts
	or
	270 Madison Avenue New York 16, New York
Igepal:	General Aniline & Film Corporation Dyestuff & Chemical Division 435 Hudson Street New York, New York
Alconox:	Standard Scientific Supply Company 808 Broadway, Dept. 5 New York, New York
Springs:	Lee Spring Company Division of Lectronics, Inc. 30 Main Street Brooklyn, New York

Heli-Coils:	Heli-Coil Division of Topp Industries, Inc. Danbury, Connecticut

3.2 Suggested Cleaning Procedures

3.2.1 Chemical Cleaning

All materials are subjected to the following steps except Al_2O_3, Copper, and Stainless Steel.

1. Scrub the part mechanically and rinse in tap water, then in acetone.
2. Vapor degrease.
3. Clean ultrasonically in hot solution of 0.05% Igepal.
4. Rinse in hot water.
5. Rinse in cold water.
6. Rinse in acetone.

3.2.2 Firing

Firing time for all materials is 20 minutes minimum.

Tantalum:	Fire at 1400 to 1500°C in vacuum
Tungsten:	Fire at 1000 to 1100°C in wet H_2*
Molybdenum:	Fire at 1150 to 1350°C in wet or dry H_2 or vacuum
Niobium:	Fire at 1250 to 1350°C in vacuum
Nickel:	Fire at 1000 to 1100°C in wet H_2
DH 142:	Fire at 800°C in wet H_2

---

* Dew point is over 10 deg. C for wet H_2.

3.2.3 Procedure for O.F.H.C. Copper

1. Scrub the part mechanically and rinse in tap water, then in acetone.
2. Vapor degrease.
3. Bright dip 1 to 2 minutes in:

275 ml	Phosphoric Acid
125 ml	Acetic Acid
100 ml	Nitric Acid
2.5 ml	Hydrochloric Acid

4. Dip directly into neutralizer (10% ammonia) then rinse in tap water, then in distilled water, then in acetone.

3.2.4 Processing of Stainless Steel

1. Scrub the part mechanically and rinse in tap water and acetone.
2. Vapor degrease.
3. Clean ultrasonically in hot solution of 0.05% Igepal.
4. Rinse in hot water.
5. Rinse in cold water.
6. Rinse in acetone.

After heliarc welding, most of the oxidation can be removed by swabbing weld area with warm solution of 50% hydrochloric acid. The part should then be rinsed well with water, then in acetone.

3.2.5 Cleaning of Aluminum Oxide

1. Scrub part mechanically and rinse in tap water.
2. Boil in Alconox and tap water for 1/2 hour.
3. Rinse in tap water for 5 minutes.
4. Fire in air 15 minutes at $1200^{\circ}C$

3.3 Generator Assembly

Figure 24 shows the generator assembly flow chart, and Figure 25 that of the generator support. The flow chart references the following assembly procedures.

1. The cable should extend 1/8 to 5/32 of an inch beyond lead sleeve. It is then melted down into a puddle, level with the end of the lead sleeve.
2. After welding, the leads will be oxidized. They are cleaned by submerging them in a solution of 50% HCL and tap water rinse. Follow with the procedure for cleaning copper, starting with the bright dip solution. The final water rinse should be ultrasonic for an extensive period of time, frequently changing the water, to insure that all chemicals are removed from the cable strands.
3. When the lead ends are welded, they tend to become rounded. Before brazing the ends should be flattened.
4. Only the shield support and the shoe piece shields are placed on the converter at this time. They will later be held in their proper position by the converter shield when it is wrapped in place.
5. Special care should be used in wrapping the converter shield so as not to flatten out the dimples. It should be snug but not tight. Also, when applying the clamping wire, care should be taken to make it snug but not so tight as to crush the converter shield.
6. All six converters which will be used in the generator should be ready for installation at this time.

550-209	Lead Sleeve	Ni	2
550-210	#4 Stranded Welding Cable (lead)	Cu	1
550-207	Lead Clamp	Nb	1
550-208	Lead Adapter	Cu	1
550-2022	.030 Wire Braze Ring	PB-130	1
550-211	Lead Terminals	Cu	1
550-2021	.030 Wire Braze Ring	BT	2
550-204	Shield Support	Ta	1
550-202	Shoe Piece Shield	Ta	5
	CONVERTER		1
550-201	Shoe Piece	Ta	1
550-203	Converter Shield (.001)	Ta	1
550-212	Wire (Clamp)	Mo	1
550-205	00-96 Hex Nut	S.S.	2
550-206	00-96 x .125 Screw	S.S.	2
550-1	Frame	Mo	1
550-17	Stud	S.S.	18
550-2001	.015 Wire Braze Ring	O.F.H.C.	18
550-11	#3585 04CN-0168 Heli Coils	S.S.	36
550-20	Stud Insulators	Al_2O_3	18
550-21	Washer (locating)	Al_2O_3	18
550-18	Washer	S.S.	18
550-19	Nut	S.S.	18
550-8	4-40 x .180 S.H.C.S.	S.S.	24
550-9	Front Cone	W	1
550-15	Washer	Mo	6
550-14	Overshield	Mo	5
550-16	0-80 x .125 Pan Head Screw	S.S.	6
550-12	4-40 x .220 Screws	Ta-W	6
550-6	Shield Insulator	Al_2O_3	1
550-4	Rear Cavity Piece	W	1
550-5	Rear Shield	Mo	8
550-3	Rear Cavity Piece Support	Nb	1
550-10	0-80 x .125 Screw	Ta-W	4
550-13	.020 Wire	Mo	1
550-2	Rear Shield Holder	Nb	1
550-7	4-40 x .270 S.H.C.S.	S.S.	6

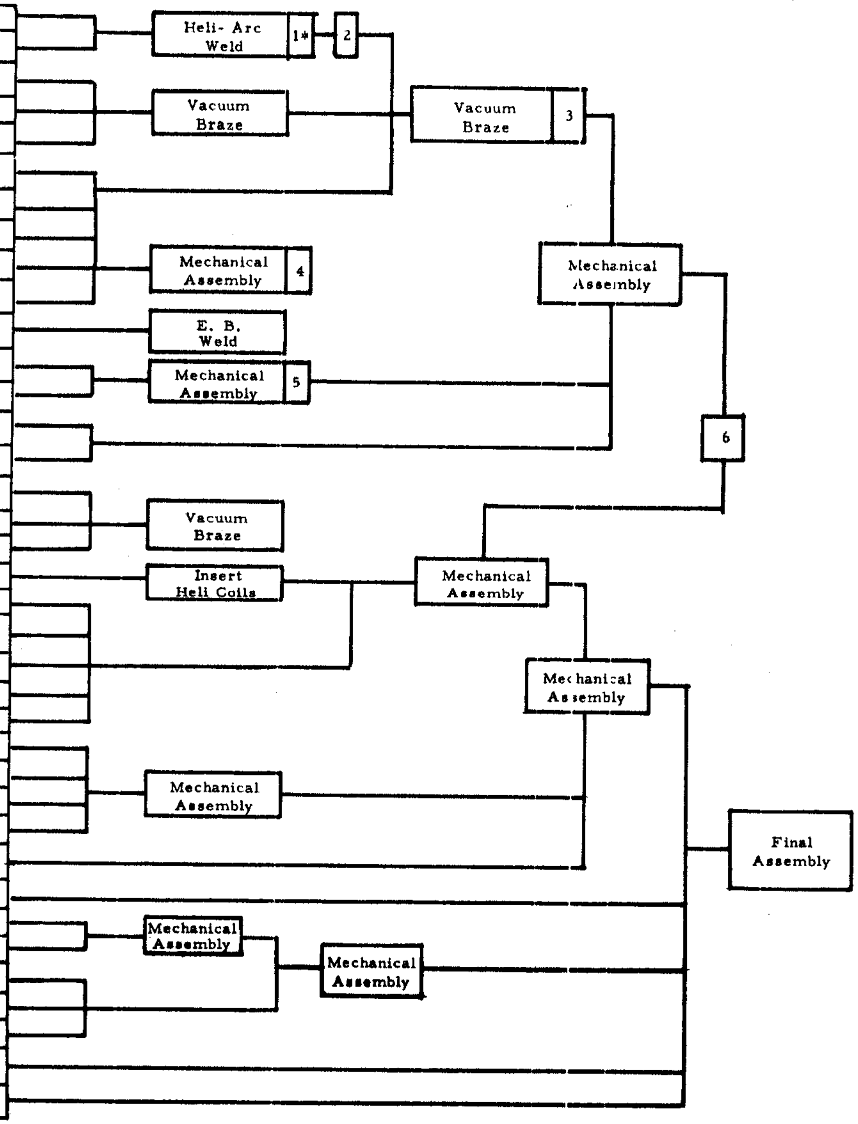


Figure 24. Generator Assembly Flow Chart

PROPRIETARY

PROPRIETARY

550-301	Web Bushing	S. S.	4
550-302	Web	S. S.	4
550-305	Support Ring	S. S.	1
550-306	Support Legs	S. S.	4
550-307	5/16-18 Hex Nuts	S. S.	4
550-307	5/16-18 Hex Nuts	S. S.	16
550-303	Insulator	Al_2O_3	6
550-304	1/4-20 x 1 S.H.C.S.	S.S.	3

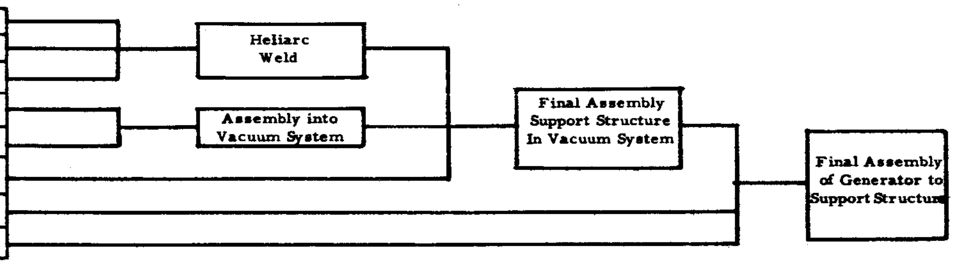


Figure 25. Generator Support Fabrication

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3.4 Electron Bombardment Unit

Figure 26 shows the electron bombardment unit flow chart which references the following assembly procedures:

1. After welding, most oxidation can be removed by swabbing welded areas with a 50% solution of HCL. If a cleaner surface is desired, the following process may be used:

Solution 1:	70% water 25% HCL 5% HNO_3
Solution 2:	80% water 20% HNO_3

   Heat both solutions to 70-80°C. Place part in solution No. 1 till it acquires a black color. Then place directly into solution No. 2. Repeat until desired oxidation removal is obtained. Then rinse thoroughly in tap water, distilled water and acetone, in that order.
2. Care should be taken to jig the parts so as to maintain proper alignment during brazing.
3. To properly insert the filaments, the straight ends should be inserted into part No. 12 first, then the bent ends into part No. 16. Screw No. 15 should be tightened first, then screw No. 13.

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549-17	Movable Support	S.S.	1
549-23	Support (Adj. Screw)	S.S.	4
549-4	Threaded Post	S.S.	4
549-8	Insulator Flange outer	DH-142	1
549-9	High Voltage Insulator	Al_2O_3	1
549-10	Insulator Flange inner	DH-142	1
549-12	Filament Support outer	Ta	1
549-21	Terminal Stud	Ta	1
549-2002	.030 Wire Braze Ring	O.F.H.C.	1
549-2003	.030 Wire Braze Ring	O.F.H.C.	1
549-2004	.030 Wire Braze Ring	O.F.H.C.	1
549-2005	.030 Wire Braze Ring	O.F.H.C.	1
549-2006	.020 thk. Brazr Washer	O.F.H.C.	1
549-11	Metal Vapor Shield	Ta	1
549-22	Traverse Adj. Screw	S.S.	4
549-6	LEE #LC-038F-1 (Spring)	S.S.	4
549-5	Spring Retainer Washer	S.S.	4
549-1	Main Support	S.S.	1
549-2	Washer	S.S.	4
549-3	#8-32 Hex Nut (height Adj)	S.S.	4
549-16	Filament Support Control	Ta	1
549-17	Lower Voltage Insulator	Al_2O_3	1
549-18	Insulator Washer	Al_2O_3	1
549-19	Washer (locating)	S.S.	1
549-20	3/8-16 Hex JAM Nut	S.S.	1
549-24	Clamp Thumb Screw	S.S.	4
549-20	3/8-16 Hex JAM Nut	S.S.	2
549-14	Filament .030 dia.	W	6
549-15	Filament Set Screw (long)	Ta-W	6
549-13	Filament Set Screw (short)	Ta-W	6

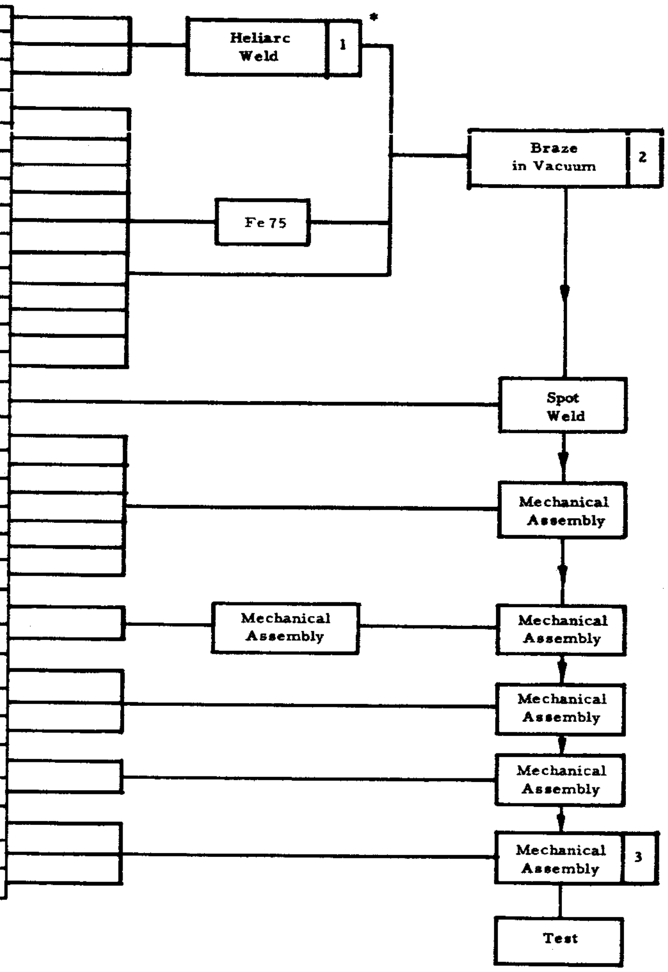


Figure 26. Electron Bombardment Unit Assembly Flow Chart

PROPRIETARY

APPENDIX A

Ideal Radiation Heat Transfer Through N Shields

Assumptions:

Edge effects are not taken into account

Conduction through shield contacts is neglected

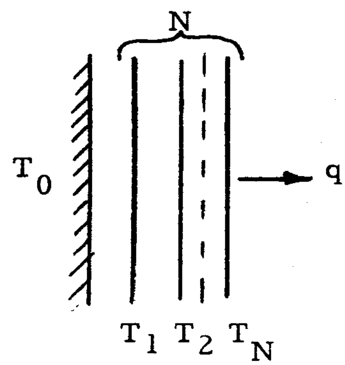
Source surface and all shield surfaces have the same emissivity ϵ

Each surface has a uniform temperature distribution

Temperature drop across each shield is neglected

Planar geometry, all shields have the same area

Using the nomenclature of the sketch, the heat transfer per unit area can then be expressed as:



(1) $$q = \sigma \epsilon (T_0^4 - T_1^4)$$

(2) $$q = \sigma \epsilon (T_1^4 - T_2^4)$$

(N) $$q = \sigma \epsilon (T_N^4 - 1 - T_N^4)$$

(N + 1) $$q = \sigma \epsilon T_N^4$$

Equating the sum of all left-hand members to the sum of all right-hand members we obtain

$$q(N + 1) = \sigma \epsilon T_0^4$$

or, $$q = \frac{\epsilon}{N + 1} \sigma T_0^4$$

In other words the shielded surface radiates with an effective emissivity equal to $\epsilon / (N + 1)$. The value of effective emissivity as a function of surface emissivity ϵ and the number of shields N is given in Figure A-1.

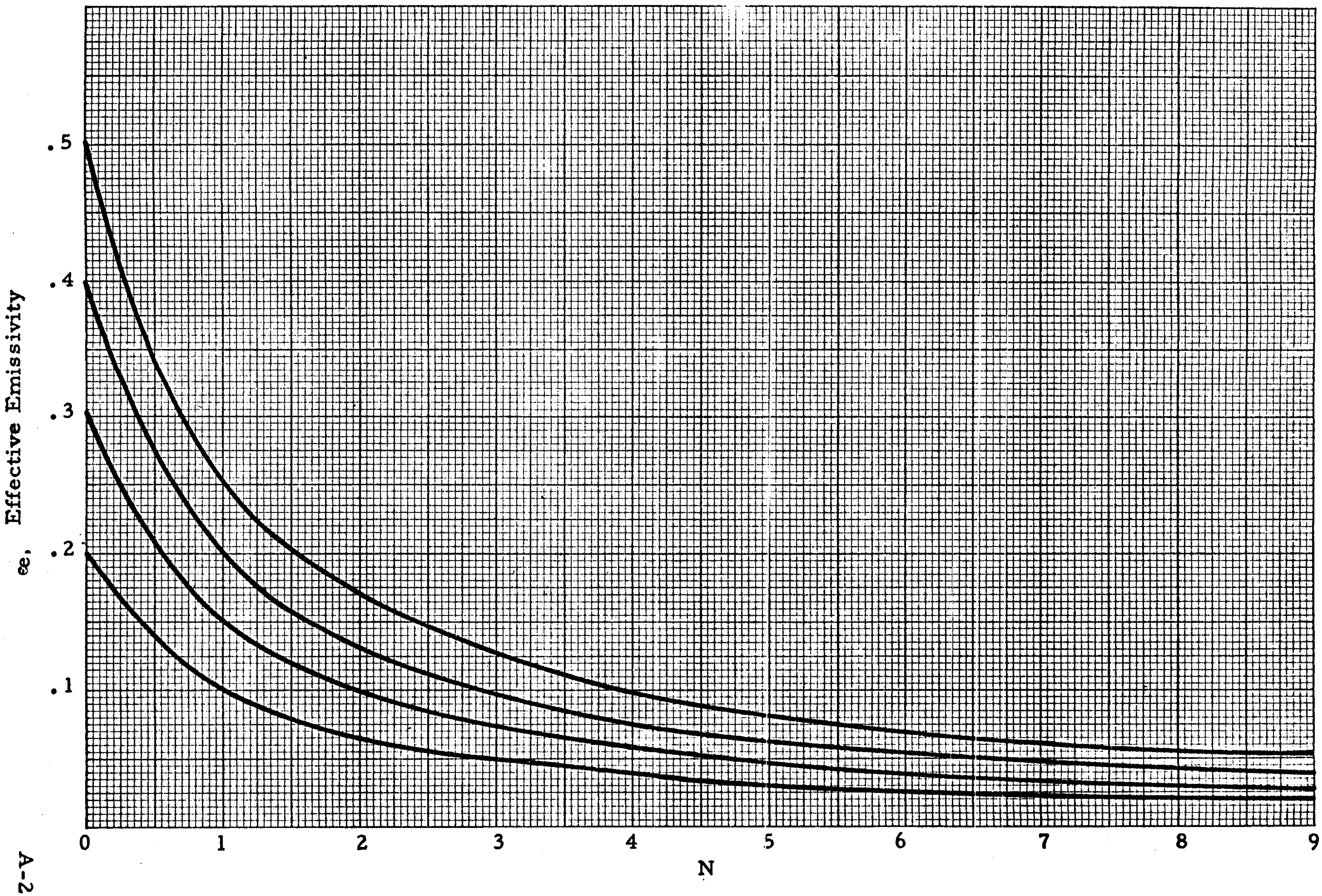


Figure A-1.